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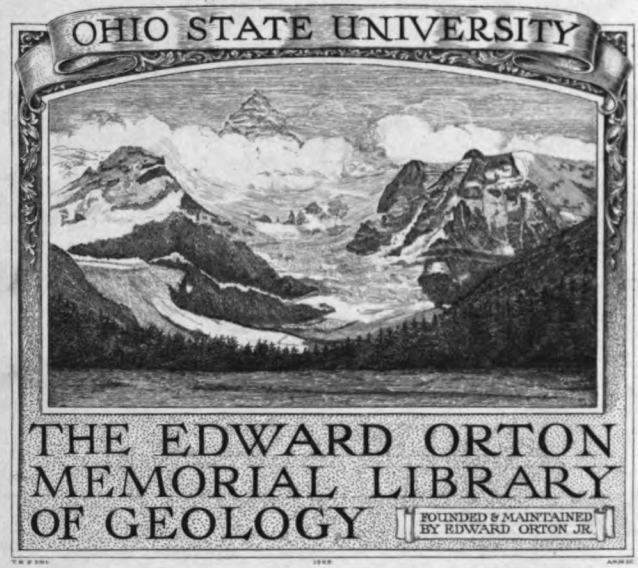

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

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OF THE

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The Editors beg to state that the Authors alone are responsible for the facts and opinions contained in their respective papers.

PETER MACNAIR, F.R.S.E., F.G.S.
JAMES W. REOCH.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. I.—Work for Glasgow Geologists—The Problems of the South-Western Highlands.

Presidential Address to the Geological Society of Glasgow, Delivered on 13th January, 1910.

By Professor J. W. Gregory, D.Sc., F.R.S., F.G.S.

By choosing as my subject the geological problems of the South-Western Highlands of Scotland, I am inviting you to wander along a rough and uncertain path. I have been led from easier subjects by habit, since it is the duty of a professor not only to teach the little he knows, but what he does not know. It is one of his most important functions to call attention to problems still unsolved, in order to incite others to advance the progress of knowledge by their solution, and to benefit by the most effective of all educational methods—individual research. It is the fascination of pioneer work that maintains the interest of those unofficial workers, who are the especial glory of British science; and most geologists would soon lose their zest and mislay their hammers if they did not stand, now and again, upon the border of existing knowledge, and make a few steps forward into the alluring, mysterious unknown. We in Glasgow are living beside a great unsolved geological problem. From my workroom window, when the weather graciously permits, may be seen an attractive range of Highland mountains; and the cloud

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wreaths that play about their summits seem to rise in notes of interrogation, tauntingly asking which is the beginning and which the end of the long succession of deposits of which these mountains are composed?

The geologist who is trying to describe the structure of the Southern Highlands of Scotland is in the position of a historian who is writing the early history of England, and is uncertain whether the Romans arrived before or after the Danes, and is not sure that Julius Cæsar may not have been a son of Edward the Confessor. Such is our uncertainty as to the relative ages of the rocks that form the Highland hills near Glasgow, although the rocks are often exposed for study in magnificent sections.

The Southern Highlands, as every member of this Society well knows, end to the south at the Highland Boundary Fault, which crosses Scotland from Stonehaven on the east to the Firth of Clyde on the west. North of that line is a wide tract of mountain country composed of bands of gneisses, schists, slates, quartzites, and limestones, which trend approximately from W.S.W. to E.N.E. or from S.W. to N.E. These rocks project westward as the picturesque peninsulas of Argyll. They rise as the chief peaks and ranges of the Grampians, and they end abruptly to the east at the straight coast of the North Sea. The rocks are bounded to the south by the Highland Boundary Fault, by which they are brought against the Old Red Sandstone. Their northern boundary is irregular, and they generally end against a vast area of grey, flaggy gneiss, which is known as the Moine Gneiss, from its development in the Moine peninsula, in north-western Sutherland. This rock is perhaps the most widespread in Scotland, and it is so uniform in character that specimens collected at Blair Atholl and Tyndrum, on its southern border, are undistinguishable from those found on the shores of the Pentland Firth. The rocks of the Southern Highlands may therefore be described as mainly a stratified, banded series of quartzites, limestones, schists, and gneisses; those between the Moine Gneiss on the north and the Boundary Fault on the south (with the exception of some slates and grits on the southern border) may be grouped together as the Dalradian System,*

* A. Geikie. Presidential Address to the Geological Society, *Quart. Jour. Geol. Soc.*, vol. xlvii., 1891. *Proc.* p. 75.

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under the appropriate name proposed by Sir Archibald Geikie in 1891.

Two of the chief present riddles of Scottish geology are, what is the age of this Dalradian System, and which is the top and which the bottom of its long succession of deposits? The study of this question is attended by two difficulties. The pre-Devonian rocks of the Southern Highlands have yielded no satisfactory fossils, although the ghosts of worms, radiolaria, and graptolites have been reported, and therefore the ordinary test for the correlation of rocks is inapplicable.* The stratigraphical method is also difficult owing to the frequent disturbance of the rocks, their variations in thickness, and the concealment of wide areas by drift and peat bogs. Even maps on a 6-inch scale may give inconclusive evidence, as the critical junctions are so often tantalisingly obscured. This area, however, has one great attraction; it is probably the most carefully and elaborately mapped large tract of stratified crystalline schists in the world. These rocks are of little economic importance, except in some mining fields, where their problems are rendered doubly intricate owing to the secondary changes in connection with the formation of the mineral deposits. In Scotland we are spared this perplexity, for the rocks are unusually barren of valuable minerals, and the geological problems of the crystalline schists are presented to us in a comparatively simple form. The magnificent maps of the British Geological Survey, on the scale of 1 inch to the mile, are now available for practically the whole of the Southern Highlands, and they are the result of the most detailed organised research yet undertaken on rocks of this character. But, in spite of the elaborate survey, there is as yet no agreement even among the surveyors as to the general structure of the area. Thus, Dr. Teall, in "The Summary of Progress of the Geological Survey for 1906" (1907, p. 1), remarks that "Further progress has been made with the mapping of the schists in the West Highland district, but as the work proceeds the difficulties of interpretation and correlation appear to increase rather than diminish. Notwithstanding

* Since this address was written more definite fossils have been discovered in the rocks beside the Boundary Fault.

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the fact that a large part of the Southern Highlands has now been surveyed, no general theory as to the structure or sequence of the rocks has been formed on which all officers are agreed. Under these circumstances it becomes necessary to eliminate theory as far as possible from the maps, and to confine the official work to the representation of the distribution of the different kinds of rock."

The last memoir on the area, issued by the Geological Survey a few months ago,* shows how fundamentally different are the views of the members of its staff. A section, on page 35, accompanied by some paragraphs above the initials of Mr. H. B. Maufe, represents the quartzites as younger than the phyllites which underlie them; while on pp. 41-42 a contribution by Mr. E. B. Bailey tells us that the real arrangement is the reverse. Where the experts of the Geological Survey have failed to agree it may be thought that the private geologist cannot give much help; but the work is now in the stage when unofficial geologists can work most profitably. The Survey maps indicate the critical points, on which the geologist can use his time to the best advantage. The Geological Survey has still large areas to map in northern Scotland, and until they have been surveyed and the geology of the mining fields has been revised we cannot expect a revision of the maps of the crystalline schists. Geology is not a stationary science, and some of the rock names and correlations adopted by the Survey nearly thirty years ago naturally require alteration or confirmation. Some of the perplexities and apparent contradictions on the maps are due to identifications of rocks that the surveyors would probably not make to-day. The maps require revision in order to confirm or correct special points. This work the private student can suitably undertake, and I appeal to the Glasgow geologists to help in our own part of Scotland.

In expressing the hope that members of the Society will amplify, and, in some respects, revise, the Survey maps, I am confident that the Survey will welcome any new facts and the suggestions of friendly criticism. There are very few

* Geology of the Seaboard of Mid Argyll. *Mem. Geol. Surv. Scotland*, sheet 36, 1909.

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maps that cannot be improved after the lapse of thirty years, and some of the sheets of the southern Dalradian area were issued in 1882, 1884, and 1888, and parts of them were prepared years earlier. I should like here to bear testimony to the extreme value and general accuracy of the Survey maps. The work has necessarily been done by many men, separately surveying different districts, and it was impossible in the early stage of the work to know what points would prove to be of greatest importance. It says much for the care with which the work of the field surveyors has been correlated and compiled that there are not more serious discrepancies between the different sheets and more important changes to be made in the identifications of the rocks. That the names of some of the rocks now require revision is no more to the discredit of the Survey than it is to the discredit of Chaucer that his spelling is now out of date. The fact that improvements can be suggested in the maps, and that a more consistent interpretation of Grampian geology than they give us may be possible is due to the work of the Geological Survey. Its maps must be the foundation of all future research.

The area of the Southern Highlands, which Glasgow geologists may most conveniently investigate, lies between the western coast and the valley of the Garry and the Tay between Dunkeld and Blair Atholl, which divides the western and eastern parts of the Southern Highlands. These South-Western Highlands include localities classical from the pioneer researches of Hutton, Playfair, MacCulloch, and Jamieson. The basis of our present knowledge was laid by Nicol, who showed that the rocks of the Southern Highlands occur in a definite succession, which prevails across Scotland. He proved this fact by several sections across the country from south to north. The truth of this view has been fully confirmed by the mapping of the Geological Survey by Dr. Horne, Dr. Peach, Mr. L. W. Hinxman, the late J. Grant Wilson, Messrs. C. T. Clough, George Barrow, J. B. Hill, J. C. Craig, and in later years by H. B. Maufe, E. B. Bailey, E. M. Anderson, G. Carruthers, and C. B. Crampton.

Their detailed mapping has shown that the Dalradian rocks occur in bands which cross Southern Scotland in a great double

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curve. It begins in the west on a course from S.S.W. to N.N.E., through Kintyre; in central Argyll it bends eastward, and crosses Perthshire from W.S.W. to E.N.E.; further east it bends northward again, and trends north-eastward across Aberdeenshire and Banffshire. A western continuation of these rocks occurs in Ireland, where it has the same trend as in Perthshire.

The succession of the rocks may be studied in a series of valleys extending south-east and north-west; one convenient section crosses from Helensburgh to Loch Awe; another from the southern end of Loch Lomond to the Bridge of Orchy; another from Callander through the Pass of Leny and Glen Ogle to Glen Lyon; and another past Dunkeld up the Tay Valley to Blair Atholl. These sections begin at the southern end with slates and grits, which are much less altered and less crystalline than the rocks to the north. They are succeeded northward by a thick series of schistose grits, which, owing to their hardness, rise into many well-known peaks, such as Ben Venue, Bed Ledi, the eastern Ben Voirlich, and Ben Chonzie. These schistose grits contain abundant clastic grains and pebbles. Toward the northern edge of these schistose grits are some bands known as the Green Beds, which also occur further north. These Green Beds often give important guidance to the disturbance of the rocks. They have been described as altered volcanic grits, but, as Mr. Clough* and Mr. Macnair† have pointed out, the evidence of a volcanic origin is not convincing. Some of the rocks mapped as belonging to the Green Beds, such as those crossed on the ascent to the Srath Dubh Uisge, a mile north-east of Ardlui, are basic intrusions.

To the north of the schistose grits and the associated schists there follows in the Loch Lomond area and Cowal a broad band of contorted gneiss and coarse quartzose schists. This band is in places 12 miles wide. This gneissic series extends eastward to the Braes of Balquhidder, where it disappears beneath the garnetiferous mica schists of the succeeding series.

* In "The Geology of Cowal." *Mem. Geol. Surv. Scotland*, 1897, p. 36.

† P. Macnair. "Geology and Scenery of the Grampians," vol. i., 1908, p. 105.

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The belt of garnetiferous mica schist includes many bands of quartz schist and the Loch Tay Limestone, and it can be traced from Kintyre and Cowal to Pitlochry; it lies to the north of the gneisses in the western area, and of the schistose grits and schists in the eastern part of our area.

The next division is characterised by the predominance of a thick bed of "phyllite," which forms Ben Lawers, the Forest of Mamlorn, part of the northern slopes of Ben Lui, and the shore of Loch Fyne past Ardrishaig. These "phyllites" generally break along smooth, glistening, micaceous surfaces; they are seamed in all directions by small quartz veins, and they have thin interbedded bands of schistose and granular quartzite. The "phyllite" is often a calcsericitic schist, which is fairly soft, and has in places acquired a secondary slip-strain cleavage. Its original bedding planes are often recognisable owing to its interstratification with quartzite.

The "phyllite" often has a quartzite or quartzitic schist along its southern margin. This quartzite is well exposed on the shore of Loch Fyne at Loch Gair.

North of the Ben Lawers "phyllite" series there is usually a black graphitic schist, and this rock is often interbedded with a schistose quartzite, well exposed at Cammoch Hill, near Pitlochry. North of this schistose quartzite follows more black graphitic schist, with which a thick series of limestones is interstratified around Blair Atholl. These limestones are often ophi-calcites, as in Glen Tilt. They were at one time regarded as a northern outcrop of the Loch Tay series, repeated by folds or faults, but they are now universally admitted to be on a different horizon from the Loch Tay Limestone. The only satisfactory distinction between the two series that I know is that the Blair Atholl Limestone is interbedded with graphitic schist and the Loch Tay Limestone with garnetiferous mica schist.

Closely associated with the graphitic schists and Blair Atholl Limestone is a thick quartzite, which is often so little altered that it is in places still a grit. It is holocrystalline, but the constituents of the rock are comparatively slightly disturbed; some blocks show structures which look like original false bedding, and many contain pebbles and fragments of felspar,

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which still show their original outlines, and have not been sheared or shattered by movement. This granular quartzite forms the Ben y Ghloe Mountains, near Blair Atholl, and a similar rock builds up many bold mountains along the northern edge of the Dalradian System, such as Schiehallion and the Islands of Jura and Islay. On the margin of the quartzite, and in Perthshire always on its northern side, are some outcrops of a coarse boulder bed, well shown in the northern foot of Schiehallion and at various localities in Argyll. The succession from south to north ends with the Moine Gneiss, of which a wide expanse outcrops to the north of the black schist or Blair Atholl series, and of the granular quartzite of Schiehallion.

A classification of this long and varied series is necessary for its correlation and for the interpretation of the geology of the Southern Highlands. The rocks may be provisionally grouped into seven divisions, named after typical localities. The names suggested are taken mainly from the central part of the area, as its sections afford the best standard for reference on both sides of Scotland. The classification suggested in the accompanying table shows the successive series and their variations and representatives, as they are followed from Islay to Central Scotland:—(See pages 10 and 11).

This table shows that the Dalradian sequence maintains the same general characters for 120 miles, across the South-Western Highlands from Islay to Blair Atholl. A somewhat similar sequence, though more disturbed by igneous intrusions, continues further eastward, until it is cut off abruptly by the North Sea, beyond which similar rocks reappear in Scandinavia.

Theories of the Structure of the Dalradian Area.

Nicol was impressed by the less altered character of the rocks on the southern edge of the Highlands, and their more intensely altered and more crystalline condition further to the north; so he concluded that the southern members of the series were the youngest and the northern members the oldest. The ordinary test of superposition is here inconclusive, for, while in the neighbourhood of Loch Lomond, the southern beds

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rest upon those to the north of them, further to the east, as north of Callander, the conditions are reversed, and the succession begins with the southern beds underlying those to the north. Nicol explained this apparent contradiction by the assumption that the beds in the eastern area were inverted, but many subsequent geologists, including, I believe, the majority of the Geological Survey, hold that Nicol was wrong in this conclusion, and that the rocks in the western area, as along Loch Lomond, are inverted, and those in the eastern area are in their original order. Mr. Macnair agrees in this respect with the Survey.

The current theories of the structure of the area may be grouped into four chief types, of which three agree as to Nicol being wrong in his interpretation of the succession. They all agree in believing that the seven series follow in one progressive sequence.

1. The first theory is based on the widely accepted view that the rocks form one continuous series ascending from south to north, and that the southern beds are the oldest. This is the conclusion which any one would almost inevitably draw from the study of the Geological Survey maps, although they represent some features inconsistent with this order of succession. This view is accompanied by many serious difficulties, with some of which Mr. Clough has wrestled in the valuable "Memoir on Cowal." He has explained some of the apparent anomalies in the succession in Cowal by a fold, of which the original vertical plane is now lying horizontally.

2. One chief difficulty in the theory that the southern rocks are the oldest is that it involves some measure of selective metamorphism, for the beds which it represents as the oldest are the least altered. Mr. Barrow's theory would remove this difficulty. He holds that the dominant fact is that the Central Highlands are the centre of an area of regional metamorphism, and that the beds are less altered as they are followed outward both to the north-west and to the south. According to this view, the Dalradian System is the southern part of a contact aureole, and therefore its least altered rocks should be those furthest to the south. At first one may be tempted to regard the great masses of Highland granites that

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Geographical Succession and Geological Correlation of the Rocks of the

Section Line.			I. Section across Islay.	II. District around and N. of Crinan Canal and Isles of Mid Argyll.	III. Loch Awe to Dunoon.
Nos. of Geological Survey Maps.			19, 27.	36.	45, 37, 29.
Stratigraphical Classification. System.	Series.	Stage.			
Lewisian			Lewisian Gneiss.[1]	—	—
Caledonian			—	—	Moine Gneiss.
Dalradian.	Schiehallion Quartzite Series.	Ardnoe Beds.	Fucoid Beds. Quartzite with Annelid Tubes.	Fucoid Beds. Annelid Quartzites.	— —
		Schiehallion Quartzite.	Islay Quartzite.	Jura Quartzites and Grits of Kilmartin.	Loch Awe Grits and Quartzites.
		Boulder Bed.	Boulder Bed on Port Askaig Conglomerate.	Scarba Boulder Bed.	Boulder Bed of Eas Bhacain and Kilchrenan
	Blair Atholl Series.	Graphitic Schist.	Islay Phyllites and Esknish Slates.	Black Schist and Easdale Slates.	Black Schist of Dalmally and Glen Domhain.
		Blair Atholl Limestone.	Islay Limestone.	Easdale and Shuna Limestones.	Limestones of Loch Awe.
		Graphitic Schist.	—	—	—
		Cammoch Hill Quartzite.	—	—	Lower Loch Awe Quartzites.
		Graphitic Schist.	—	—	—
	Ben Lawers Series.	Ben Lawers Phyllites.	Port Ellen Phyllites.	Craignish Phyllite.	Ardrishaig Phyllite.
		Loch Gair Quartzite.	Laphroaig Quartz Schist.	—	Loch Gair Quartzite.
		—	—	—	—
		—	—	—	—
	Loch Tay Series	Garth Schists (Garnetiferous Mica Schist).	—	—	Garnetiferous Mica Schist.
		Loch Tay Limestone.	—	—	Glendaruel Limestones.
		Pitlochry Schists (Garnetiferous Mica Schist).	—	—	Garnetiferous Mica Schist.
	Loch Lomond Series.	Northern Green Beds.	—	—	Green Beds.
		Gneisses of Loch Lomond.	—	—	Albite Schists.
		—	—	—	Loch Goil Schistose Grits.
		—	—	—	Ardentinny and Loch Eck Gneiss.
		Ben Ledi Grits and Green Beds.	—	—	—
		—	—	—	—
Post-Dalradian	Aberfoyle Series.	Aberfoyle Slates.	—	—	Dunoon Slates.
		Aberfoyle Grits.	—	—	Bull Rock Grits.
Cambrian	Boundary Fault Series.		—	—	—

[1] Some "Torridon Sandstone" occurs S.E. of the Lewisian in Islay.

I have not examined the areas in columns I. and II., nor the Schistose Grits and associated Slates in columns VII. and VIII.

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South-Western Highlands, in Sections generally from N.N.W. to S.S.E.

IV. Through Ben Lui to Loch Lomond.	V. Ben Vannoch and Forest of Mamlorn to East of Loch Lomond.	VI. Bridge of Balgie (Glen Lyon), *via* Lochan na Lairige, Glen Ogle, and Pass of Leny to Callander.	VII. Glen Tummel, through Schiehallion, Taymouth, and Loch Freuchie, to Dallick, on Glen Almond.	VIII. Along Valley of Garry and Tay, through Blair Atholl and Dunkeld.
46, 38.	46, 38.	46, 38.	55, 47.	55, 47.
—	—	—	—	—§
Moine.	Moine.	Moine.†	Moine.	Moine.
—	—	—	—	—
—	—	—	—	—
Glen Strae Quartzites.	—	—	—	Ben y Ghloe Quartzite.
—	—	—	Schiehallion Quartzite.	—
			Boulder Bed.	
—	—	—	Graphitic Schist.	Graphitic Schist.
—	—	—	Kinardochy Limestone.	Blair Atholl Limestone.
—	—	—	Graphitic Schist.	Graphitic Schist.
—	Ben Vannoch Quartzite.	Meall Corranaich Quartzite.	Cairn Mairg Quartzite.	Cammoch Hill Quartzite.
—	Graphitic Schist of Loch Lyon and Ben Heasgarnich.	Graphitic Schist N.W. slope of Ben Lawers.	Graphitic Schist.	Graphitic Schist.
Stob Garbh Phyllite.	Mamlorn Phyllite.	Ben Lawers Phyllite.	Ben Lawers Phyllite.	Ben Lawers Phyllite.
—	Pubil Quartzite (Glen Lyon).	—	—	—
Quartzites of Eas Daimh.	—	Coire Liath Quartzite (N. foot of Ben Lawers).	—	—
Black Schist of Ciochan Ben Lui.	—	—	—	—
Garnetiferous Mica Schists of Ben Lui, Ben Chuirn, and Ben Udlaidh.	Garnetiferous Mica Schists of Ben Achallader and Tyndrum.*	Garnetiferous Mica Schist of Meall Liath.	Garnetiferous Mica Schist of Garth Castle.	Garnetiferous Mica Schist of Creag Dhubh.
Ben Duchraige Limestone.	Loch Tay Limestone.	Loch Tay Limestone.	Loch Tay Limestone.	Loch Tay Limestone.
Garnetiferous Mica Schist.	Garnetiferous Mica Schist.	Garnetiferous Mica Schist of Meall an t-Seallaidh (N. of Balquhidder), and the Stob.	Aberfeldy Garnetiferous Mica Schists.	Pitlochry Garnetiferous Mica Schists.
Green Beds and Grits of Crianlarich.	—	Grits of the Stob.	—	—
—	—	—	—	—
Tullich Hill Schistose Grits.	Gneiss of Ben a' Choin and Loch Lomond.	Gneiss and Schists of Braes of Balquhidder.	—	—
Loch Lomond Gneiss.	—	—	—	—
Green Beds of Glen Mallochan and Sron Aonaich.	Green Beds of the Trossachs.	Green Beds of Glen Fathan.	—	—
Grits of Ben Bhan.	Schistose Grits of Ben Venue.	Schistose Grits of Ben Ledi.	Schistose Grits of Ben Chonzie.	Dunkeld Schistose Grits.
Luss Slates.	Aberfoyle Slates.	Lubnaig Slates.	Dallick Slate.	Birnam Slate.
Creachan Grits.	Aberfoyle Grits.	Leny Grits.	Glen Almond Grits.	Obney Grits.
Balmaha Boundary Fault Beds.	Boundary Fault Beds.	Leny Slates.	—	—

* Not marked on Map 46, but outcropping along the Fillan at Tyndrum.
† Coloured on Survey Map as Quartzite.
A gneiss of Lewisoid aspect occurs intrusive into the Quartzite at Meall Greaim, N. of Blair Atholl.

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are so conspicuous in the geological map of Scotland, as the cause of this metamorphism. But, as Mr. Barrow has shown in an important paper,* these granitic massifs were later than the metamorphism, and cannot be its cause. He attributes the metamorphism to the intrusion of a less conspicuous muscovite-biotite granite, which is widely distributed in some areas in numerous small masses and veins. These granite veins are shown, for example, on the map of the Blair Atholl district (sheet 55), where they occur in the Moine Gneiss to the north of a fairly well-defined line.

Mr. Barrow accepts the usual view that the northern beds are the youngest, and he regards the Moine Gneiss as on the same horizon as the Highland Quartzite, of which he regards it as simply a flaggy variety,† the difference being due to the different geographical conditions under which they were deposited.

I should like to express my great personal indebtedness to Mr. Barrow for the trouble he has taken in explaining matters to me, and for the contagious enthusiasm with which he has stimulated my interest in these problems, when, under pressure of other work, it has seemed to wane.

To Mr. Barrow we owe three most important steps forward. (1) He clearly recognised the identity of the Strowan flags to the north of Blair Atholl with the Moine Gneiss of Sutherland; (2) we owe to him the proof that the Blair Atholl Limestones and the Loch Tay Limestones are on different horizons; and (3) that in the Glen Tilt Valley, the Blair Atholl series rests unconformably upon the Moine Gneiss.

I therefore recognise Mr. Barrow's brilliant service to Scottish geology, and am sorry that I cannot follow him in his view, that the Moine Gneiss, the Cammoch Hill Quartzite, and the Schiehallion Quartzite are on the same horizon.

3. A third theory as to the general structure of the Southern Highlands is that of Mr. Macnair, which he has ably expounded

*G. Barrow. "On an intrusion of Muscovite-Biotite Gneiss in the South-Eastern Highlands of Scotland." *Quart. Jour. Geol. Soc.*, vol. xlix., 1893, pp. 330-336.

†G. Barrow. "Moine Gneisses of the East Central Highlands, and their position in the Highland Sequence." *Quart. Jour. Geol. Soc.*, vol. lx., 1904, p. 400.

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in a series of papers in the *Transactions* of the Philosophical Society of Glasgow, and in his great work, "The Geology and Scenery of the Grampians" (Glasgow, 1909). Mr. Macnair lays much stress upon the influence of folds and fan structures. He describes the country as composed of a series of great folds, the axes of which run parallel to the strike of the Dalradian rocks. Mr. Macnair describes the central anticline as having the structure of an Alpine fan, and he adopts for it the German word for a fan, "Fächer"; its axis is represented as passing along Loch Awe and through Ben Lawers, and Mr. Macnair's ancient Grampians are assigned their greatest height along this line. A parallel fan or "Fächer" is assumed to have once existed to the south of this line, and to have foundered beneath the Midland valley of Scotland.

According to Mr. Macnair, the southern rocks of the Dalradian sequence are the oldest, and the black shales or slates near Aberfoyle and Callander are the oldest beds in the Southern Highlands. As Mr. Macnair regards the Moine Gneiss as being on the same horizon as the Highland Quartzite, he places it at the top of the Dalradian System. If so, and if the Lewisian and Moine Gneisses are one series, as is held by some geologists, then the beds beside the Boundary Fault, marked as Silurian on some of the Survey maps, should be the oldest rocks in Scotland!

4. The further theory, which I only know from partial statements in the Survey publications and in a short newspaper summary, is that of Mr. E. B. Bailey, who accepts Nicol's view that the oldest beds are to the north, and he explains the difficulties in this view by the theory that the beds in the northern area have been inverted by great overfolds.

The Age of the Dalradian System.

1. *Relations to Palæozoic and Possible Lower Palæozoic Rocks.*

The age of the Dalradian System is still problematic. It is certainly older than the Old Red Sandstone, which rests unconformably upon it. But it is not in direct contact with any rocks that are admitted by all geologists to be Lower

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Palæozoic. Nicol, in 1844, represented the Dalradian schists as a metamorphosed continuation of the Silurian and Ordovician rocks of the Southern Uplands of Scotland. He abandoned this view in 1863, and then concluded that the rocks of the Southern Highlands were more ancient than any of those in southern Scotland. Nicol's earlier view of the Silurian or Ordovician age of the Dalradian schists has been reasserted from their relations with a remarkable series of rocks that has been found at intervals along the Highland Boundary Fault from the North Sea to Arran, and reappears in the same geological position in northern Ireland. This series includes limestones, cherts, black shales, and slates, and some amphibolites due to the alteration of basic igneous rocks. This series is thickest in eastern Scotland, as in the valley of the two branches of the Esk River. Their development there has been well described by Mr. Barrow,* who regards them as including two distinct groups—a Jasper and Green series—covered unconformably by a series of grits and slates—the Margie series. These border rocks are exposed in Glen Sannox, in Arran, and they are well known to Glasgow geologists from the sections near Balmaha and Aberfoyle.

Nicol thought that the cherts of this series might be altered Old Red Sandstone; and they have a striking resemblance to the cherts of the Arenig series in the Southern Uplands. Fossil radiolaria were identified in a microscopic slide prepared from a specimen of these cherts. The rocks were therefore identified as Arenig, and were accordingly marked as "Silurian" or "Silurian?" on the Geological Survey maps. The reported fossil, however, was not regarded as convincing, and most stress has been laid on the stratigraphical and lithological evidence as to the age of these rocks.† Neither is very satisfactory. Mr. Barrow tells me that at Glen Sannox there are indications of these rocks resting unconformably on the

*G. Barrow. "On the Occurrence of Silurian (?) Rocks in Forfarshire and Kincardineshire along the eastern border of the Highlands." *Quart. Jour. Geol. Soc.*, vol. lvii., 1901, p. 330.

†Dr. Horne allows me to state that Dr. G. J. Hinde has recently identified as radiolaria some bodies recognised in the cherts from Gualann, east of Balmaha, by Dr. Peach. This important discovery strengthens the probability of the Lower Palæozoic age of the cherts and their associated rocks.

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crystalline schists of the Highlands, and such an unconformity seems probable; and his sections show that in the valley of the Esk the chert series, or Highland Border series, is bounded to the north by Highland schists forced over them by an overthrust fault. The sections in the tunnel of the Loch Katrine aqueduct, 4½ miles south-west of Aberfoyle, show that there also the Highland Border series is separated from the rocks to the north by an overthrust fault. Careful search, however, along the outcrop of these beds for proof of unconformity has failed to yield convincing results, and there are four rival theories as to the age and origin of the Highland Border series—

(1) According to Mr. Macnair, it is an integral part of the Highland schist series, and, as its rocks dip underneath the others, he holds that it includes the oldest rocks of the Southern Highlands.

(2) Mr. Barrow, on the contrary, regards it as younger than the Highland schists, and he identifies it, on grounds of lithological similarity, with the pre-Cambrian Briovarian series of Brittany.

(3) According to Dr. Peach and the Survey maps they are "Silurian" (*i.e.*, Ordovician).

(4) A fourth possibility is that the Highland Border Fault series includes rocks of two distinct origins—(*a*) Some of the shales have been most carefully searched for fossils, as they appear so little altered that if they were Ordovician one would certainly expect to find graptolites in them; but I am disposed to agree with Mr. Macnair that there is no striking lithological difference between these black slates and the slates of the Aberfoyle series to the north of them. (*b*) The limestone appears to be of secondary origin. It occurs along the Boundary Fault, and there is a similar limestone on the continuation of this fault, where it brings the Upper and Lower Old Red Sandstones together, and also west of Loch Lomond, where it brings the Lower Old Red Sandstone against Lower Carboniferous rocks. Mr. Tyrrell has examined the limestones microscopically, and he regards the post-Lower Devonian rock from the west of Loch Lomond as identical in character with that from the Boundary Fault west of Aberfoyle. The limestone on the western side of Loch Lomond is clearly a fault

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rock, younger than the Old Red Sandstone and Lower Carboniferous, and that just east of Balmaha is younger than the Upper Old Red Sandstone; and there seems no reason to regard the similar limestone nearer Aberfoyle as of a different origin.

The relations and age of this Boundary Fault series are both still uncertain. It seems to me that they are either the uppermost part of the series which includes the Aberfoyle slates and grits, or a younger series, separated from the Aberfoyle series by a still doubtful unconformity and by the absence of cherts from the Aberfoyle series.

Either conclusion would leave us dependent on lithological evidence for the age of the Highland schist series. The Dalradian rocks were at first claimed by Murchison as Palæozoic, since he correlated the limestones with those of Durness, then identified as Silurian. He therefore regarded most of the southern schists as Silurian and other Lower Palæozoic sediments, which had been altered to schists at some post-Silurian date. There is no evidence for the correlation of the Durness Limestones—now assigned to the Lower Cambrian—with either those of Loch Tay or Blair Atholl. Sir Archibald Geikie has suggested that this Dalradian System is a complex of pre-Palæozoic and Palæozoic rocks, tangled together, and then so metamorphosed that it is impossible to separate the Palæozoic from the pre-Palæozoic constituents. On that view the metamorphism is necessarily of Palæozoic age. Professor Bonney has expressed* his conviction that if the Highland schists include Palæozoic rocks we shall be still able to separate them. I share Professor Bonney's hope, and, as a working hypothesis, regard the Dalradian System as pre-Cambrian, and even pre-Torridonian.

2. *Relations to the Torridonian and Lewisian.*

There is no evidence as to the relations of the Dalradian and Torridonian rocks in the Glasgow district, but in Islay Dalradian "phyllites" and quartzites are faulted against a rock identified as "Torridon Sandstone (?)," and as the Dalradians appear to maintain their normal characters up to this sand-

* *Quart. Jour. Geol. Soc.*, vol. lvii., 1901, p. 345.

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stone they are most probably pre-Torridonian. This conclusion is further strengthened by the discovery by Messrs. Wright and Bailey* of pebbles of Highland Quartzite in the Torridon Sandstone at Colonsay. It is true that there is no known case of an outlier of the Torridon Sandstone resting upon the Dalradians; but, considering the extreme denudation which the country has undergone, this is not surprising, and the negative evidence does not shake my faith that the Dalradian System is pre-Torridonian.

It is almost certain that the Dalradian System is younger than the Lewisian, though on the mainland they are nowhere in contact. Meall Gruaim, in Glen Tilt, consists of a coarse banded gneiss, of which hand specimens would probably be identified as Lewisian. At first I was tempted to regard this rock as an exposure of underlying Lewisians, brought up as an inlier by the parallel faults along Glen Tilt; but on a later visit, with the University geology class, the sharp eyes of some of the students found a contact, which shows that this coarse "Lewisoid" gneiss is intrusive into the quartzite.

3. *Relations to the Moine Gneiss.*

The most important problem at present in regard to the stratigraphical position of the Dalradian System is its relation to the Moine Gneiss. I understand that Dr. Peach and some members of the Geological Survey staff regard the Moine Gneiss as the metamorphosed representatives of the Torridon Sandstone, and therefore as younger than the Dalradians. Hence there is a strong weight of authority in support of the conclusion that the Moine Gneiss is post-Dalradian, while according to the succession upheld by Messrs. Barrow and Macnair, it is a member of the uppermost division of the Dalradians. I feel unable to accept either conclusion, for typical Torridon Sandstone occurs in close juxtaposition with typical Moine Gneiss on the eastern side of Kyle Rhea, a little north-west of Glenelg, and as both rocks retain a remarkable uniformity in character over wide areas it would require very clear evidence to prove that the passage from

* Geol. Surv., *Summary of Progress*, 1907 (1908), p. 72.

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gneiss to sandstone had happened there in a few yards. Dr. Horne does not accept the relatively late Torridonian age assigned to the Moine Gneiss, and, encouraged by faith in his judgment and authority, I hold that the Moine Gneiss is not only pre-Torridonian, but pre-Dalradian.

The strongest argument against this conclusion is the claim that the Moine Gneiss passes imperceptibly into quartzite, and into the ordinary mica schists of the Dalradian. This view seems to me based upon identifications that require revision.

Various materials are marked on the Survey map as quartzite which I regard as Moine Gneiss. Thus, on sheet 46, a band of quartzite is marked as crossing Glen Lyon at Mor Shuas and Ros, above the Bridge of Balgie, and extending eastward to Creag Dhubh, which is beside the road from the Bridge of Balgie past Lochan na Lairige to Loch Tay. The stratigraphical relations of this quartzite, as shown on the map, and assuming it to be the Highland Quartzite, would be very puzzling. The difficulties disappear if the rock be accepted as a siliceous variety of Moine Gneiss. Again, the rock along the burn at Druimchastle, 1½ miles east of Kinloch Rannoch, marked on the Survey map (sheet 55) as quartzite, is a well-banded biotite gneiss similar to the Moine.

The recently issued map (sheet 45) might be read as suggesting the passage from the quartzites about Glenstrae, north-east of Dalmally, into Moine Gneiss. The "Memoir," however, describes these two rocks as quite distinct in character, and says the quartzite apparently overlies the Moine.

There are, I think, at least four distinct rocks included on the Survey maps as the quartzite, viz., typical Moine Gneiss and quartzites belonging to three distinct horizons.* One of these rocks, the Schiehallion Quartzite, is a gritty, non-schistose rock. It forms the upper part of Schiehallion, the mass of the Ben y Ghloe Mountains, and it is unconformable on the black or graphitic schist (the Blair Atholl schist). The second quartzite, which may be called the Cammoch Hill Quartzite, is interbedded in the black schist. The third is a

* The existence of quartzites on at least two distinct horizons is clearly recognised by the Geological Survey at Glen Creran. J. G. Wilson, Geol. Surv., *Summary of Progress*, 1904 (1905), pp. 63, 64; *Ibid.* 1905 (1906), p. 91.

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quartzite at the base of the Ben Lawers "phyllite," and, as it occurs at Loch Gair, on Loch Fyne, it may be called the Loch Gair Quartzite. It appears to be on the same horizon as the Glencoe Quartzite, and that name may be adopted for it. But as Glencoe is off the main Dalradian band, it would be more convenient to adopt for this horizon a name taken from the southern and typical Dalradian area.

The argument for the gradual passage of the Moine Gneiss into quartzite was founded on early identifications of gneiss as quartzite, and, though occasional hand specimens of the two rocks may be indistinguishable, their separation in the field seems always practicable. The evidence for the passage of Dalradian Quartzite into Moine Gneiss appears therefore unconvincing, while the evidence from the superposition of the Dalradians on the Moine seems to me conclusive that the Moine is the older formation. That this superposition was due to later deposition was first clearly shown by Mr. Barrow in Glen Tilt, where he discovered a bed of Blair Atholl Limestone resting upon an eroded surface of Moine Gneiss. This section has been twice visited by the geological class of the University, and its members were all convinced of the truth of Mr. Barrow's view. That section seems conclusive that the Blair Atholl Limestone was deposited unconformably upon the Moine Gneiss.

A second case of superposition of Dalradian upon Moine occurs around Ben Achallader, at the head of Glen Lyon, where the Ben Achallader schists, a great mass of garnetiferous mica schist, capped by the quartzite of the peak of Ben Achallader, rests upon the Moine Gneiss. The two series are separated by a band of hornblende schist, represented as an intrusive sill, but it would be easier to understand the persistence of horizon of this hornblende schist if it be a metamorphosed basic lava, instead of an intrusion.

Ben Chuirn, to the north of Ben Lui, supplies a third case of the superposition of Dalradian schist on Moine Gneiss. The mountain consists of a sheet of garnetiferous mica schist, extending northward over an underlying platform of Moine Gneiss.

A little further west, according to Messrs. Clough and

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Bailey,* the flaggy quartzite near the foot of Allt Broighleachan, in Glen Orchy, which belongs to the Dalradian System, rests upon the Moine Gneiss.

Further evidence for the pre-Dalradian age of the Moine is given by the great N.N.E. to S.S.W. faults. Their down-throw side is generally on the east, and they repeatedly bring the Moine Gneiss on the west against Dalradians on the east, indicating that the latter are the higher beds.

It may be suggested that if the Moine is pre-Dalradian, some Dalradian outliers should occur upon the vast area of Moine Gneiss in the Northern and Central Highlands. Denudation has, however, been so active there, that but few pre-Devonian remnants have been left; but there are some. Thus, according to Mr. E. M. Anderson,† Highland Quartzite and associated Dalradian schists occur on the Moine, north-east of Carr Bridge.

The Unconformity of the Dalradian on the Moine.

Not only do I think that the Dalradian System is younger than the Moine, but it seems to me that there is clear evidence that its various members transgress on to the Moine, showing that they were laid down unconformably on the sinking margin of a northern land. I know of no case where the Loch Lomond Gneiss, the Ben Ledi grits, or Aberfoyle series are in contact with the Moine Gneiss; but four of the five Dalradian series occur unconformably upon it. Thus, the garnetiferous mica schists of the Loch Tay series rest upon the Moine Gneiss at Ben Achallader and at Ben Chuirn, south-west of Tyndrum, and in Glen Lyon. The Ben Lawers "phyllite" is in contact with the Moine near Mor Shuas, in Glen Lyon, and, according to Messrs. Clough and Bailey, the Moine is capped by the quartzite which underlies the Ben Lawers "phyllite" in Glen Orchy. The limestones of the Blair Atholl series rest on the Moines in the section photographed by Mr. Barrow‡ at Glen Tilt.

* Geol. Surv., *Summary of Progress*, 1907 (1908), p. 63.

† Geol. Surv., *Summary of Progress*, 1905 (1906), p. 109; and 1906 (1907), p. 85.

‡ G. Barrow. *Quart. Jour. Geol. Soc.*, vol. lx., 1904, p. 430.

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The Schiehallion Quartzite appears to rest on the Moine to the south-east of Kinloch Rannoch, though I have not examined that junction closely.

Hence, four of the five series of Dalradian rocks rest in place upon the Moine. The unconformity of the Dalradian system and the transgression of its subdivisions upon the older Moine Gneiss to the north appear to be two of the clearest facts of Grampian geology.

Hence the Dalradian System appears to be below the Torridonian and above the Moine Gneiss. The position suggested for it is shown in the following table:—

Archeozoic,	Torridonian,	
	Archean,	Dalradian.
		Caledonian (Moine Gneiss, &c.).
		Lewisian.

The Order of Deposition of the Dalradian Series.

The second great problem in the geology of the Grampians is which is the top and which the bottom of the Dalradian System. According to Nicol, its southern members are the youngest, but, according to the Survey and Mr. Macnair, the reverse is the fact. Both views are attended with difficulties.

Six facts as to the succession seem clearly established. The first is that the Schiehallion Quartzite unconformably overlies the black schists. This fact appears to be proved by the evidence of the Ben y Ghloe Mountains, and less clearly at Schiehallion.

Secondly, Mr. Barrow's evidence that the Blair Atholl Limestones and their associated black schists were deposited upon the Moine Gneiss appears convincing.

Thirdly, that the black schist of the Blair Atholl series is younger than the Ben Lawers "phyllite" seems to follow from the evidence of, amongst other places, Ben Heasgarnich, south of Loch Lyon; of Cammoch Hill, near Pitlochry; and of the northern slopes of Ben Lawers, as shown by Mr. M. Macgregor.

Fourthly, that the Ben Lawers "phyllite" overlies the Loch Tay Limestone series with its garnetiferous mica schist is shown by the outlier of the Ben Lawers "phyllite" on the

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summit of Ben nam Imirean. Others (which I have not personally examined) are mapped (sheet 46) at Meall Ghaordie and Ben Dheiceach.

That the Ben Lawers "phyllite" is on a higher horizon than the Loch Tay series seems further shown by the great increase in width of the outcrop of the "phyllite" to the east of the Auchlyne Fault. The beds there have been folded, and the width of the central bed must be increased on the downthrow side if it be a synclinal, and on the upthrow if an anticlinal. The downthrow side of the fault is almost certainly to the east, and as the outcrop of the "phyllite" is much increased on that side, the fold is a syncline, and the "phyllites" must be underlain by the garnetiferous mica schists.

Fifthly, that the Loch Tay Limestone series consists of three members—(*a*) An upper series of garnetiferous mica schist, the Garth schists, which forms the summit of the mass of Meall an t-Seallaidh, north of Balquhidder; (*b*) the calcareous or limestone division; and (*c*) a lower series of garnetiferous mica schist, the Pitlochry schists.

Sixthly, that the garnetiferous mica schist of the Loch Tay series rests on the Loch Lomond series is clear from the evidence of the Stob (Meall na Frean), north of the Braes of Balquhidder, and of the country south-west of Crianlarich.

The five northern series of the Dalradian System therefore seem to occur in the following descending series:—

5. Schiehallion Quartzite.
4. Blair Atholl series.
3. Ben Lawers series.
2. Loch Tay series.
1. Loch Lomond series.

The relations of the two series of rocks south of the Loch Lomond Gneiss, viz., the Ben Ledi and Aberfoyle series, to the Dalradian System are, however, very uncertain. We might expect that as the northern series are arranged in a sequence descending from north to south, the same succession would continue southward to the Boundary Fault, and this, the simplest natural explanation, is now generally adopted. There are, however, such serious objections to it that I hesitate to

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accept it. Thus, the rocks of the Aberfoyle series are much less altered than those further north, and if they are the oldest beds underlying the others we should expect them to be at least as much altered as the supposed younger beds in the neighbourhood. If we accept Mr. Macnair's theory they would be the nearest known rocks to the centre of his great southern fan. They should therefore have been exposed to greater heat and pressure, and should be more altered and crystalline than the rocks immediately to the north of them. The slates and some of the grits are, on the contrary, comparatively unaltered.

Moreover, the Survey maps suggest that the two southern series are unconformable to the Loch Lomond Gneiss.

(1) Between Loch Lomond and Loch Katrine the Aberfoyle slates are separated from the northern gneiss by schistose grits, but west of Loch Lomond the northern bands of schistose grits are not marked on the map, which represents the slates resting directly on the schists, as in the ridge running W.S.W. from the Paps, west of Luss.

(2) The Ben Ledi schistose grits appear to transgress over the Loch Lomond Gneiss, until at Balquhidder they come close to the Loch Tay Limestone series; and at Strathyre the schistose grit is represented as coming against both the Loch Tay Limestone and the upper garnetiferous schists of the Loch Tay series.

(3) The pebbly bands in the schistose grit are most developed on the northern side, as at Ben Vane, west of Loch Lubnaig.

It might, however, be suggested that the patches of schistose grit shown on the map (sheet 38) north-west of Loch Katrine may be outliers of the Ben Ledi grits. I have not seen them, but they may be the same rock as the "schistose grit" of Tullich Hill, south of Arrochar, and of the shore of Loch Long, 3 miles north of Whistlefield, and that rock appears to me to be on a distinct horizon from the Ben Ledi grits.

It will, of course, be asked whether any members of the northern Dalradians correspond to the Ben Ledi and Aberfoyle series. Neither of these series extends far to the north. There are neither outliers nor inliers of them on the outcrops of the three northernmost series; nor is there anything in the northern Dalradian similar to them.

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There seem to me three possible explanations of the position of the Ben Ledi and Aberfoyle series. The first is that these two series are Dalradian, and that they represent the period of the great unconformity between the Schiehallion Quartzite and the black schists. The second is that they are both post-Dalradian.

The third possibility is that the Ben Ledi schistose grits are Dalradian, and belong to the Loch Lomond series, while the Aberfoyle series is post-Dalradian. On the whole, that view seems to me the most probable, though my examination of the evidence on this part of the problem has been so far inadequate for a confident opinion.

I am therefore disposed to think that Nicol's view as to the sequence of the Southern Highlands was right in part, and that the descending succession is from south to north in the southern part of the South Highland rocks. That view has, however, been abandoned by most Scottish geologists. This doctrine is now held only by a "Wee Free" school, of which, so far as I know, Mr. E. B. Bailey and myself are the only members, and as I hold only to one-third of the six articles in the Nicol creed, I fear that Mr. Bailey would reject me as a weak adherent of the faith.

I was at first tempted to accept Nicol's succession for more members of the Dalradian series from three considerations—

(1) The southerly dip of some of the least disturbed areas.

(2) The probability that as the descending sequence from north to south is true along the northern edge of the Dalradians—where, as at Blair Atholl, the limestones rest on the Moine Gneiss, and also, though less certainly, for the two groups of rocks along the southern edge of the Southern Highlands—the same order would hold for the intermediate area.

(3) A further tempting argument in favour of the north to south succession is its agreement with the sequence that holds through most British geology. Our oldest rocks outcrop in northern and western Britain, and were built up of sediments from the old continent of Arctis that occupied the site of the North Atlantic. As a rule, in British geology the oldest beds outcrop to the north-west, whence there is a long ascending

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series going south-eastward to the mouth of the Thames and the coasts of Essex and Suffolk. The same order holds in the Southern Uplands of Scotland, for, in spite of their complex folds, the resultant succession is ascending from north to south.

This analogy is, however, I believe, deluding, and another more instructive comparison may take its place. The true agreement is not with the general order of deposition of British sediments, but with the disturbances that elevated the great mountain chains which have determined the structure and geography of Europe.

The chief existing mountains in Europe belong to the Alpine System, which was formed in middle Cainozoic times by pressure, usually exerted from south to north. The rocks were bent into folds and thrust northward in crumpled masses against the old masses of rock—the tectonic Forelands—so-called by Suess because they kept back the mountain waves, just as a promontory of land keeps back the waves of a rising tide at sea. In the Alps the youngest rocks and the greatest overfolds are on the northern slopes of the chain.

To the north of the Alps are the fragments of an older mountain system, found in southern Ireland, southern England, France, Belgium, and Germany. Bertrand called them the Hercynian Mountains, and Suess the Armorican and Variscan Mountains; and recently Suess has included them as part of a mountain system which, from its analogy with the Altai Mountains in Asia, he calls the European Altaids. This mountain system was formed toward the end of the Palæozoic, in Upper Carboniferous and Lower Permian times. Like the Alps, this chain was due to pressure acting mainly from south to north, and the younger beds generally occur on the northern side. Thus, in the Alps, the Archean and Lower Palæozoic rocks are confined to the southern Alps, while the Mesozoic and Cainozoic beds predominate in the northern Alps; and in the old Armorican chain the Archeans are well developed in Brittany, while its northern side in Devonshire is composed of younger rocks.

Again, further to the north than the Alpine or Armorican Mountains are the remains of a third great mountain system,

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whose fragments occur in northern Ireland, Scotland, and Scandinavia. It was much older than either the Alpine or Armorican systems, for it was formed by disturbances at the end of the Archean, and even earlier than the Torridonian.

In these mountains there is the same tendency to occur in great bow curves, as in the Alps and the Altaids; and we may suspect the former existence of a solid block of Archean rocks to the north-west of Kintyre, from the southern strike of the Dalradian beds in that peninsula.

As with the Alps and the Altaids, the greatest overfolds were probably on the northern slopes, and it would be natural to find them in such northern localities as Glen Etive, to the north of the main Dalradian band, where their existence is claimed by Messrs. Maufe and Bailey.

I should therefore summarise the geology of the South-Western Highland as follows:—The country is composed of a series of Archean rocks, which are mostly altered sediments, and extend in approximately parallel bands across Scotland, and those between the Aberfoyle series, on the south, and the Moine Gneiss, on the north, may be grouped as the Dalradian System. This system is pre-Torridonian, and younger than the Moine Gneiss, on which the northern beds rest unconformably.

The oldest member of the Dalradian system is the Loch Lomond series, to the north of which there is an ascending series in the following order:—

4. Blair Atholl series.
3. Ben Lawers series.
2. Loch Tay series.
1. Loch Lomond Gneiss.

Although for the Dalradian area the descending sequence is from north to south, on the southern margin there is a series of grits and slates younger than the rocks to the north of them, on which they have probably been deposited unconformably.

The Grampians are therefore one fragment of the worn-down base of a great pre-Cambrian, and even pre-Torridonian, mountain chain, which extended from Ireland to Scandinavia.

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This mountain chain was probably formed by rocks being pressed against the old resistant land that stood to the north-west of the British area. The main movement was from south to north, though in some cases, as along Loch Eck, the displacements moved the upper beds southward and the under side northward.

The superficial part of the folded layers may have been compressed into Alpine fans, but in the deeply buried roots of these mountains the main folds were probably subdivided into numerous small secondary crumplings, as we find the folds subdivide below in the lower depths of folded mining fields. The rocks now exposed on the surface then probably lay so deeply that their compression gave rise to an intense puckering, instead of to the larger folds of the Alps. The southern continuation of these Dalradian mountains must, as Mr. Macnair has repeatedly maintained, have risen high over what is now the Midland Valley of Scotland.

These pre-Torridonian Grampians probably had a great extension westward beyond the British area, and they probably caused the desert climate of Scotland during the deposition of the Torridon Sandstone. I once observed the orientation of a dozen wind-cut pebbles in the Torridon Sandstone on both Quinaig and on Canisp. The pebbles showed that the prevalent direction of the wind in Torridonian times was south-westerly, as at present. The country could not therefore have had a desert climate if the winds had just blown ashore from an ocean. They must have come either across high mountains or over a wide land area that extended far westward into the Atlantic. The western continuation of the Archean Grampians probably dried the south-westerly winds, and as they fell, warmed by the loss of moisture and by their descent down the eastern slopes of the mountains on to the lowlands, they gave the country its arid climate.

My subject has carried me far, from the succession of the schists and sandstones, of limestone and quartzites in our own Highland hills, to wide questions of Continental structure and Archean climate. But the especial interest of geological research is that, while its data must be collected locally, its conclusions are often of a wide-reaching significance. Hence,

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when I urge the members of this Society to devote a larger share of attention to the Highland rocks than in the past, I am inviting them to work which must be prosecuted in the attractive scenery of our Highland hills and glens, and which may help to elucidate the geology of Scandinavia and the early structural geography of Europe. The questions involved are, no doubt, complex and difficult, but much of the further information necessary to remove those complexities could be collected by a careful, though comparatively elementary, student. Many of the problems can be solved by simple mapping in the field without necessarily involving microscopic petrology.

Unsolved problems and gaps in our knowledge of the Dalradians present themselves on all sides, and the following may be noticed as examples of the opportunities for useful work presented to Glasgow geologists:—

(1) There is no detailed account of that thick series of rocks known as the schistose grit of the Ben Ledi series. A full description of the successive beds of which that series is composed would be new knowledge, and should be very instructive.

(2) The confirmation or disproof of the possible unconformity between the Aberfoyle series and the Ben Ledi grits.

(3) Further evidence of the unconformity of the Schiehallion Quartzite on the graphitic schist series.

(4) A detailed section across the Ben y Ghloe Mountains to show the extent of their folding and the original thickness of the quartzite.

(5) Further study of the boulder beds, including the identification and numerical proportion of the rocks present in them, and an effort to determine, by examination of the original top and bottom of the boulders, the original base of the boulder bed.

(6) Careful study of the outliers of the Aberfoyle slates on the Loch Lomond series, with special reference to the evidence of shattering by inversion.

(7) The relations of the Loch Tay Limestone near Strathyre to the schistose grits.

(8) Confirmation of the suggested unconformity of the Highland Fault series to the Dalradians at Glen Sannox.

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(9) The nature of the rocks mapped as outliers of the schistose grit on Loch Lomond Gneiss near Ben Lomond and Loch Katrine. Are they the same rock as the schistose grit of Tullich Hill and Loch Goil, or do they belong to the Ben Ledi grits?

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No. II.—Carboniferous Rocks of the Solway, Scotland.

By John Smith.

[Read 10th February, 1910.]

On the Solway, fringes of Lower Carboniferous rocks occur in six districts.

1. From White Port to Abbey Burnfoot.
2. From Abbey Burnfoot to Airds Point.
3. From the Urr Water to Gutchers Isle.
4. From Portowarren to Portling.
5. Near mouth of Southwick Water.
6. From Southerness Point to Hogus Point.

Inland they rest unconformably either on Silurian strata or on granite of the Criffel-Dalbeattie mass, and probably at places on remnants of Old Red Sandstone, and at parts are faulted against the older rocks.

1. White Port to Abbey Burnfoot.

At White Port, a small bay, with neither houses, harbour, nor road, Silurian strata (probably of Ludlow age, and closely resembling the thin-bedded strata of that formation on the Greenock Water, near Muirkirk) are seen in the tideway, with a steep dip to the N.W. On the high bank above, the Carboniferous strata dip to the S.E., but the junction between the two formations is obscured by débris and vegetation. The junction is probably an unconformity—not a fault—as there is a basal conglomerate with abundance of bits of Silurian rocks. Here the "Survey" got the Carboniferous fossil *Syringopora ramulosa*. Parts of this conglomerate are cemented by limestone.

The next conglomerate higher up, and separated from the last by a band of red shale, is 10 feet thick, and conspicuous from the large quantity of white quartz pebbles it contains, there being a few pebbles of metamorphosed Arenig chert in it. No other conglomerate on the Solway exactly resembles this beautiful rock, and a large part of it is kept clean by the waves.

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Between White Port and Abbey Burnfoot the rocks consist mostly of sandstones, grits, and conglomerates, sometimes in massive beds, occasionally separated by beds of reddish mudstone. One of the beds is a dark brown sandstone, and some of the conglomerates are pretty coarse, containing pebbles of greywacke, porphyrites, and felstones, but I saw no granite pebbles in this section. Sun cracks are sparingly seen, and the only fossils I observed were obscure plant remains.

North of Abbey Head grey sparkling sandstone, with rejuvenated quartz, dips at 50° to E.S.E., and contains a few pebbles. One of the sandstone beds has got nodular masses, or concretions—"Kingle Bools"—sometimes several feet in diameter, often pretty globular, and these, where cut across by joints and weathered, show generally a number of concentric rings formed by gutters and ridges. These concretions occasionally run together, forming irregular masses.

Inland, where the Carboniferous rocks outcrop to the N.W. on Wall Hill, there are two small quarries where good building sandstone is worked.

2. Abbey Burnfoot to Airds Point.

At Abbey Burnfoot the Silurian rocks come down to the shore and so prevent for a short distance the continuity of the Carboniferous fringe at that part.

From Abbey Burnfoot to Port Mary the rocks are mostly coarse, grey sandstones, some of them brown, and some fine-grained, a few of the beds showing strong, oblique stratification. There is a little red and grey fakes with obscure plant remains. Very little limestone occurs in this section—a thin band of grey limestone in a sandstone bed shows vermicular weathering. The conglomerates have all small pebbles. The rocks dip generally pretty steeply towards the Firth, and this, combined with the number of large blocks from the cliffs, has rendered it a very difficult coast to traverse. At one point the shore rocks dip at 40°, and the cliffs above at 10-15°, showing that there may be an unconformity or anticline here. Towards Port Mary the dip decreases to about 20°.

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If there is not a fault in Port Mary Bay, where the rocks are hidden by gravel, the coarse conglomerate on the N.E. side of the bay must be higher in the series than those already noted. On the E. side of the bay the dip again increases to 40°, and there are many barite veins in the conglomerate.

Opposite Rerwick Park the dip decreases, sometimes to as little as 10°, and there are beds of red limestone from 1 foot or so up to 4 feet in thickness. It is impossible to say how many of these red limestones occur, but at one part three are seen separated by beds of fine conglomerate and red mudstones. These limestones often contain pebbles, but I saw no fossils in any of them. Some limestone nodules in sandstone look as if they had been built up in concentric layers. The red staining—sometimes bright red—of the limestones of the Rerwick coast appears to have been coeval with their deposition, as there are grey limestones both above and below them.

From the sandstone of the Rerwick coast Dundrennan Abbey was built, and much durable sandstone could be obtained here.

Orroland.

The rocks on the Orroland shore are the finest-grained of any to the S.W. of the Merse, and consist largely of sandstones with occasional conglomerates. There are several beds of both grey and red limestones, some of the grey being crowded with fossils, and one of the red beds having abundance of them. Some of the limestone bands appear to be entirely destitute of fossils, and most of them contain pebbles and sand grains, the latter often in abundance, although others look exceedingly pure. The red limestones of Rerwick and Orroland may be compared with the red chalk of Hunstanton, similar conditions as to the staining of calcareous sediments having occurred at widely different periods of the earth's history. The red limestone, which contains abundance of fossils, is deeply guttered, and worn into pot-holes by the waves, so that lumps are easily knocked off. The grey fossiliferous limestones, on the other hand, have been worn smooth, and show abundance of fossils in section, but it is next to impossible to break off a bit with an ordinary hammer.

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All the limestones of Rerwick and Orroland have probably—in large measure—been formed from limey material drifted from parts of the sea bottom during oscillations of the earth's crust, and generally lie between beds of sandstone, occasionally with thin bands of reddish shale or mudstone interposed.

If the Orroland rocks are the equivalents in point of time to those at Arbigland (to be noted further on), then, generally speaking, they must have been deposited in shallower water; but probably they are on a lower horizon. The conditions of deposit here seem to have been quite favourable to the growth of the astræiform *Lithostrotions* and *Productus giganteus*, abundant at Arbigland, but apparently absent here.

At the Orroland boathouse, on the underside of an overhanging ledge of red sandstone, there is the finest display of fossil seaweeds I have seen anywhere, both above and below the sandstone there being a bed of conglomerate, dip 15° to S.

In the Orroland rocks *Lithostrotion fasciculatum*, *Syringopora ramulosa*, and *S. gigantea* occur, and these were the only corals I saw, the *Syringopora* being mostly in its living position. *Corophioides polyupsilon* occurs in reddish sandstone. We will meet with it again.

The sandstone beds here contain few fossils; some tracks 1 inch to ¾ inch wide occur, and there are a few obscure plant remains.

About halfway between the Orroland Waterfall and Barlocco Heugh there is a grey, fine-grained sandstone dipping at 25° to S.S.E., and at right angles to the bedding there is abundance of single tubes in it 12 inches deep now filled by gritty sandstone, and the only thing I can compare them to are the burrows of spout fish (*Solon*).

Barlocco Heugh, viewed from a point a few hundred yards to the S.W., exhibits an imposing spectacle of coast denudation, the large display of thinly stratified bands in the foreground adding greatly to the scenic effect, the dip being E.S.E. at 25°. This heugh rises from the shore line to a vertical height of over 100 feet, and is composed of dark purple sandstone and conglomerate, the latter greatly prevailing, with pebbles up

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to 20 inches, but few reach 1 foot, a lot of them being of felstone and some of granite. Under the sandstone and conglomerate there is a red marl with irregularly shaped nodules of red and grey limestone, apparently unfossiliferous. It is astonishing how far the cliffs may sometimes be undermined by the waves before they topple over, this being owing to the few joints that traverse the rock, and in the high and dry caverns the surface of the sandstone may be rubbed off by the fingers—probably the salt spray does the abrading work.

At N. end of Barlocco Heugh there are great beds of conglomerate with little sandstone and large blocks, a well-rounded, hard grit I measured being 4 feet by 2 feet 6 inches. The bedding here is very irregular, like that often seen in the glacial drift, there being a few pebbles of granite in the conglomerate.

In Barlocco Bay the rocks are mostly obscured by gravel, and at its N. side sandstone dips to S.E. at 20°.

Castle Muir cliffs form a magnificent escarpment, 120 feet high, of thirty beds of red sandstone, and when viewed from the S. side there is seen to be an anticline, the beds in the cliffs dipping gently inland, those on the shore as gently seaward. From here to Rascarrel Burn there is a dip to N. of 10-30°, so that the Castle Muir strata are lower in the scale than those of Rascarrel. With the exception of an occasional band of red sandstone, all these rocks are coarse red or purple sandstones—some of them muddy—with odd pebbles of granite, &c., &c., but there are no conglomerates, no limestones, and no fossils, with the probable exception to be noted. On the faces of the cliffs and roofs of the undercut alcoves there are magnificent displays of natural fretwork, a frequent feature in the weathering of red sandstone, but here it seems to have reached its climax of magnificence. The shore rocks are cut up by deep tidal gutters, and there is a large cave into which the tide enters, and a smaller one a little above high-water mark. There are not many caves in the Carboniferous rocks of the Solway, the probable reason being that the strata nearly always dip more or less towards the Firth.

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In Rascarrel Bay the sandstone dips N.N.W. at 30°.

Near Lochanling cottage the rocks have been somewhat disturbed, the dips being to E., W., and N. at 10-35°. North-east of this there is a great quartz vein cutting through grey sandstone, and varying in thickness up to 21 feet—a rare feature in Carboniferous strata. It is of white quartz, and I saw no minerals in it.

North-east of Lochanling, on the raised beach, a barite vein was worked in sandstone, but is at present abandoned. The shore rocks here are pretty flat, some of them almost level, and on the surface of a sandstone bed there are abundance of markings, one of the most complete being 7 inches long, and composed of twenty-two oval protuberances, increasing gradually in size from $\frac{3}{16}$ to $\frac{1}{2}$ an inch. They are of sandstone, and the only thing I can compare them to is the siphuncle of an *Actinoceras*.

The next rock which requires special attention is a reddish conglomerate, 80 feet thick, the pebbles being mostly angular, and the rock closely resembling the Permian (Trias) conglomerate of Ballantrae. The bottom, 20 feet, has got layers of red mudstone, and is conspicuous from the number of white barite veins which cut through it. The rocks here dip 20-60° to S.E. Then comes a boulder bed, 11 feet thick, with blocks up to 2 feet in diameter.

Some distance below the above, and embedded in sandstone, there is a floor of granite blocks, the largest ones exposed being 2 feet in size—they are mixed with pebbles, mostly of granite. A comparison of these granite blocks and pebbles with the granite *in situ* a little inland showed that both are of the same quality.

From here to Airds Point the rocks are mostly gritty sandstone, but with occasional blocks and pebbles, some of granite, an angular one of greywacke being conspicuous in the stratification, and measuring 3 feet 6 inches by 2 feet 6 inches.

At Airds Point the Carboniferous rocks end, and, although they are the lowest on the shore, the junction with the underlying strata is not seen, and the section is as follows:—Silurian rocks much disturbed and the stratification destroyed. A breccia of Silurian rocks and bits of porphyrite nearly in a

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vertical position. Carboniferous strata, which look as if they had been deposited up against the last bed (just as we see the Solway sandy-mud deposited against perpendicular cliffs at the present time). The Carboniferous rocks have been slightly tilted, and the junction may be a fault, but there is nothing to suggest this—no broken rock and no curving up of strata.

From Airds Point to the mouth of Auchencairn Bay there are high sea cliffs of Silurian rocks with the strata much folded, the sections equalling in interest those on the opposite side of the country north of St. Abb's Head. In the mouth of Auchencairn Bay granite dykes cut through Silurian strata.

3. Urr Water to Gutchers Isle.

There are no Carboniferous rocks now for a distance of $3\frac{1}{4}$ miles, when they again make their appearance beyond the mouth of the Urr Water, just to the E. of Castle Hill Point, where they are seen to rest against the granite, as in the following section:—Granite of Barcloy Hill. Carboniferous basal conglomerate dipping to the Firth at about 80°. Stacks of Carboniferous sandstone in the tideway. From the manner in which the Carboniferous strata turn up, and lie against the granite, there appears to be a fault, but from the great number of granite pebbles in the conglomerate the Carboniferous strata had evidently been deposited on the granite.

From Glenstocking quarry, where sandstone was worked, the Survey have recorded *Syringopora ramulosa*.

The Glenstocking inlier of Carboniferous rock is a small one extending along the shore for less than a mile, consisting mostly of sandstone, with bands of conglomerate holding pebbles of granite, porphyrite, greywacke, and quartz, the normal dip being S.S.E. at 20°. On the E. they are again probably faulted against the granite, but the junction is not seen, the dip being S.W. at 10°. Before the introduction of the French burr the Glenstocking inlier supplied all the S.W. of Scotland with millstones.

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4. Portowarren to Portling.

Silurian strata and the granite of White Hill occupy the coast for 1¼ mile, when the Carboniferous strata again appear at Portowarren, and continue to Portling, a distance of 5 furlongs, where they are succeeded by shore cliffs of metamorphosed Silurian rocks in the condition of hälleflintas, traversed by porphyrite dykes. This section of Carboniferous rocks is composed mostly of sandstones, none of them red, although some are conspicuously spotted with red from the large quantity of granitic débris they contain, this arkose feature being common in many of the sandstone beds of the Solway.

There are a good many bands of grey limestone, and although I devoted several days to this part of the coast I did not see a single fossil in any of the limestones. One of the limestones has got rounded masses of crystallised dolomite, this bed having evidently been altered from a carbonate of lime to a carbonate of magnesia. The globular shape of the hollows in this limestone is peculiar, as hollows in limestone so altered are generally very irregular in shape. Some of the limestone bands are in sandstone without any intervention of shale, but there is usually some shale or mudstone between them.

There are no red limestones or mudstones here, such as occur in the Rerwick coast sections. There is not much conglomerate, but that seen contains granite pebbles. The Survey have recorded *Bellerophon urei*, *Modiola modioliformis*, and *Orthoceras* from this section, and I saw a few obscure plant remains in it.

From Portling to near the mouth of Southwick Water, a distance of 2¼ miles, there are no Carboniferous rocks, the coast cliffs consisting of hälleflintas, dipping at steep angles, porphyrites, felstones, and at one part the granite of Bainloch Hill comes down nearly to the shore. To this point so great has the recent denudation of the Solway coast been that it is generally in sheltered places only that bits of the raised beaches are left, the wave action of the present sea-level having cut away the rocks and obliterated the beaches under the 100-foot contour. At Spouty Dennans there is a low, old rock beach left, 40 yards wide, the higher ones having

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been cut away during the time this old one was formed; a large talus of cliff blocks has accumulated on it.

Before the discovery of Carboniferous fossils in them, the strata of Portling, Glenstocking, Orroland, and Rerwick were classed as Permian.

5. Southwick Inlier.

Near the mouth of Southwick Water there are some old sea stacks of Carboniferous rocks rising from the Solway mud. They consist of conglomerates, with pebbles of greywacke, felstone, &c., and dip to the S.E., being probably connected under the Merse low-lying lands with the Southerness Carboniferous rocks.

6. Southerness Point to Hogus Point.

A walk of 5 miles along the Solway sands brings us to the Southerness Carboniferous rocks, the first seen being S.W. of the lighthouse. Here there is a considerable diversity of dip, and some faulting, the strata consisting largely of limestones, a dark grey, thin-bedded series of them containing the greatest thickness of this rock to be seen anywhere on the Solway, dipping E., N.E., and E.N.E. at 10-20°. There is a small anticline here. The bands are mostly barren of fossils, but some of them are literally made up of organic remains. The Survey record *Spirifera cuspidata*, a shell not got in the Carboniferous rocks of Scotland. It occurs in a thin "zone," of a few bands of limestone and shale, 50 yards due west of the largest boulder in the tideway. No corals have been recorded from these rocks, and I only saw *Lithodendron fasciculatum*, rare; *Stenopora tumida*, abundant in one layer; *Monticulata inflata*, scarce; so that they are likely to be on a different horizon from those at Arbigland, now to be described. The other fossils in the Southerness group have all been found in the Arbigland series.

A bit of the western part of the Southerness Limestone series shows crushing, the shales having a roughly schistose appearance, the limestone bands having been broken up into

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longish bits like rough "sets," both the schistose structure and long direction of the limestone fragments having a strike in a S.S.E. direction.

Arbigland.

From Southerness north-eastward along the coast, skerries occur in the tideway, and opposite the shore end of the road at Thirlstone the best exposures of these beds, which strike nearly parallel to the coast, are seen, and from high-water mark to about half-tide dip at about 50° to E., but towards low water the dip is in the opposite direction, so that here a peculiar syncline occurs, the strata repeatedly nosing out to the south, and in plan looking as if a number of the front parts of open boats had been packed inside one another. The beds consist mostly of sandstone, with occasional shales and some bands of impure limestone. The presence of *Platyostomella* in these strata stamps them as belonging to the Calciferous or lower division of the Carboniferous rocks in Scotland, and this is the view as to their age held by the officers of the Survey, although they do not record the above shell. The most prominent bed in this series is the Thirlstone Sandstone, which appears to occupy the highest position of it, and is a massive bed with many of the bands much curved—(Plate IV., Fig. 2)—and occasional instances of cross-stratification, the material, for the most part, being moderately fine-grained, but sometimes gritty.

At the N. end of the great mass of Thirlstone Sandstone there is a small fault at high tide, which increases in throw seaward. I mention this specially, as at a first glance the young geologist might interpret this feature as representing an unconformity.

From the prominent N. end of the Thirlstone Sandstone on to opposite Arbigland garden the dip of the strata is not at such a high angle as further south; and at the above place they wheel sharply round, the ultimate strike being to the N.W.

For a distance of 70 yards the strata are much curved and twisted, and although the bends are often pretty sharp, still, the breakages in the thinner beds are remarkably few, but

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the Thirlstone Sandstone has been rendered almost unrecognisable from the way in which it has been broken up. Bits of the strata in this much-disturbed area have been reduced to dust (now recemented) or much brecciated, this being most marked in connection with some of the sharper folds.*

From the very complicated way in which the strata of this little area has been folded it looks as if the lateral pressure had been applied from different directions at different times.

The fossils of the Calciferous Series are, as a rule, so poorly preserved that the specific characters cannot always be determined.

Calciferous Fossils.

Platyostomella scotoburdigalensis.
Spirorbis lelicteris.
Bivalves, crusted with shale.
Spirals, ,, ,,
Dentalium.
Leperditia, band of dark shale crowded with them.
Megalichthys hibberti.
Rhizodopsis granulatus.
Lithodendron (Lithostrotion) fasciculatum.
Crinoid débris.
Sea Weeds.
Long, winding burrows.

Lower Limestone Series (in Part).

By and by reasons will be given for supposing that the strata occurring above the Thirlstone Sandstone belong to the

* In the discussion which followed the reading of my paper, one of the members—thinking he could improve on my description of the above much-disturbed area—compared the stratified folds (when being bent) to the slipping on one another of the steel plates of a carriage spring. This comparison is, I think, an unfortunate one. In the first place, the plates of such a spring are bent when hot, and the weight of the carriage is always tending to straighten them, more or less; and in the second place, the plates are rigid and suffer neither extension nor compression in the bending, their ends being free to move. With beds of rock folded by lateral compression (taking, say, a bed 1 foot thick composed of several thin bands, by way of illustration), the tendency in the outer bands of the curve would be to *stretch*, whilst those in the inner bands would be *compressed*, so that instead of the bands slipping on one another, as rigid plates, it would be the particles of the rock which would do so, and if the lateral compressing movement was slow enough, there might be few breakages in certain parts of the folded strata.

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Lower Limestone Series (Scotland), and although this is considered to be so, still no part of the Hurlet Limestone and shales are here represented, the Arbigland beds evidently occurring at a lower horizon.*

From the curved and crushed zone of rocks northwards the beds of the Lower Limestone Series dip almost at right angles to the strike of the Calciferous strata above described, and at a gentle inclination, this continuing in the tideway to a short distance N. of the Arbigland gardener's house. The dip of the strata now changes to the opposite direction, so that here we have a great synclinal bend, the beds forming the N. limb dipping at quite as gentle an angle in the opposite direction. Where the alteration of dip takes place there is a basin in the strata extending from half-tide to low water, measuring 90 yards from N. to S., and 80 from E. to W., the dip all round being at a gentle angle inwards. This feature has been humorously called the "Crannog," and is of great convenience as a "land mark"—when the tide is out.

At M'Culloch's Castle—an old fort—there are, in the plantation, sea cliffs with similar fossils to those in the tideway rocks.

Proceeding northward the strike of the rocks runs at an oblique angle under the shore gravel, there being little alteration till Hogus Point is reached, when the angles of dip to east increase to 45°, and after this the strata become fairly vertical. Further N. the dip is E.N.E. at angles of from 45° to 85°, the strike in the rather flat tideway here exhibiting sometimes long, gentle curves and occasional sharp flexures, with a few small anticlines and synclines, a distance of 200 yards of strata measured across the strike being laid bare at low tide. North of this the great area of the Solway sands covers up the rocks.

The great feature of this unique section is the thin-bedded nature of all the strata. They consist of limestones, generally impure; shales, none of them bituminous; nodular bands in

* I may say that the Survey consider these strata to belong to the Calciferous Series, and on Sir A. Geikie's Map of Scotland (1876) they are also relegated to that horizon.

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the shales; sandstones often pretty limey, and probably none of them entirely free from lime, some of them with large unfossiliferous concretions. The sandy limestones after having been exposed to the weather for some time exhibit the edges of thin laminæ having been built up of repeated layers, the purer ones being massive.

The nodules in the shales are of three qualities—irony ones, cement ones, and others light in colour, the two former containing plenty of fossils, although odd ones may have none, the latter quality having very few. Some of the nodules contain a little zinc blende.

Fossils of the Lower Limestone Series.

The great feature, and, to the geologist, charm, of the Arbigland shore is the immense number of fossils to be seen in the rocks in the tideway, and to be got by hammering from the nodules and some of the limestone bands. The first fossils to command attention are the beautiful corals, for the reason probably that such a series is not to be seen anywhere else in Scotland. The astræiform varieties of *Lithostrotion* occur in isolated masses, generally in the shaley beds, occasionally in some of the sandy limestones, but are never seen to coalesce. The Lithodendroid *Lithostrotions* sometimes cover areas of several square yards, and occasionally coalesce. *Syringopora* coalesces, for many yards, and is also abundant as single masses, often of small size. The rugose corals are scarce, but one species, *Amplexus cylindrica*, reaches a large size and ponderous weight—one fragment measured 18 inches long. *Syringopora*, *Aulopora*, *Cladochonus*, *Michelinia*, *Lithostrotion*, *Stenopora*, and *Monticulipora* may all occur in one band, but often one form predominates in certain bands.

In some of the corals of the *Portlocki* type the cells are filled with bitumen and when specimens are broken a strong odour of that substance is given off. If the bitumen has not come from the decomposition of the coral animal it is difficult to understand where it originated, there being no bituminous shales in connection with the corals. In the Nettlehirst quarry, near Giffen station, bitumen is occasionally seen in some of the

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larger rugose corals, but it is by no means a common substance in corals.

Crinoids are comparatively scarce, but some thin layers are crowded with their débris.

A *Productus*, resembling a small *giganteus*, is probably the commonest fossil in the Arbigland strata, and is seen in bed after bed of the shale and limestone, even in rather sandy bands with seaweeds; frequently occurs in closely packed scalps, and is generally in its living position, but often upside down. Its shell has sometimes been burrowed into by a parasite of some kind, probably a sponge (Plate I., Fig. 1).

In nearly all the sandy bands seaweeds occur, often beautifully preserved, some of the laminarian-looking stems reaching to over an inch in diameter and several feet long, so that these beds seem to have been deposited in a depth of water answering to that of the "Laminarian Zone" of the present day.

The trails of *Crossopodia* are not common, occurring in the sandy beds, and as represented by two species, *Plinthoderma* and *Enteromorpha*, are very rare.

What look like nests or open burrows are seen in crowds on some of the thin, sandy limestones, the round ones measuring $\frac{3}{8}$ to $\frac{1}{4}$ of an inch in diameter, and are $\frac{1}{2}$ an inch deep; long ones 1 inch by $\frac{1}{4}$ inch, and $\frac{3}{8}$ inch deep. (Plate II., Fig. 1.)

On the surface of one of the thicker sandstone beds there are numerous pits, 4 inches by 3 inches and 3 inches deep, which are evidently the washed-out burrows of *Corophioides polyupsilon* (Plate IV., Fig. 1), as in one of them there was the last dwelling which the animal had made—generally the only one that is perfectly preserved in this peculiar fossil, every dwelling but the last necessitating the more or less complete deformation of the one preceding it.

Depth of Water.

Evidently none of the strata of this series were deposited in any great depth of water, although there were apparently during their deposition repeated oscillations as to level, the general tendency, of course, being downwards in the great

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Carboniferous synclinorium. There are no beds of pure limestone, and although the individual corals have sometimes reached respectable dimensions—a *Lithostrotion* measures 6 feet by 4 feet*—still there never was time allowed for the large ones to coalesce and form continuous beds of limestone till floods of mud came and put a stop to their career, there having been sufficient commotion in the water to triturate shells and form impure limey bands with their débris; even the massive *Lithostrotions* and lighter *Lithodendrons* have been torn up from their growing positions and laid on their sides, or even turned upside down. The thickest *Lithostrotion* seen measured 13 inches.

There are no indications of shore conditions, no beds of conglomerate having been observed, and although ripple marks sometimes occur they do not prove these beds to have been deposited in tideways. On some of the bands, however, there are what look exceedingly like sun cracks, as if extensive muddy flats had been exposed at times, and perfect specimens of *Productus giganteus* occur with them.

Geological Age of the Arbigland Series.

In the West of Scotland, between the Calciferous Series and the Lower Limestone Series, there is a great thickness of volcanic rocks attaining to more than 1000 feet, and made up of a series of flows, often differing greatly in quality, and it is but natural that we should look about us for stratified rocks contemporaneous in age to these volcanics. At Arbigland there are no volcanic rocks between the Thirlstone Sandstone (Calciferous) and the upper beds (Lower Limestone Series, in part). In the Arbigland series 213 species of fossils occur, which, with a few exceptions, are found in the Lower Limestone Series of the West of Scotland. There is, however, one striking difference between the two series, and that is in the corals, the *Lithostrotions* of the astræiform types are abundant at Arbigland, whilst in the Lower Limestone Series

*The *Meandrina* of the tropics is said to require several centuries before it reaches its full growth, so that this specimen may have attained to a respectable age.

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of the West of Scotland one may not see half a dozen specimens in half a century, and, so far as one can judge, the conditions prevailing during the deposition of the later strata were far more favourable to the growth of a coral fauna than were those of the Arbigland area, and abundance of corals occur in them, so that the occasional specimens got in the Lower Limestone Series of the West of Scotland were evidently "the last of the Mohicans," so far as the astræiform type of the *Lithostrotions* are concerned. Similar remarks apply to the genus *Syringopora*.

The upper Arbigland, the Hurlet, and the Beith White Limestone form but one Palæontological series, the Hurlet having at the close of the great volcanic episode received the greater part of its fauna from the former, or, as will be seen further on, probably from a sea bottom a little above it.

Blackwoodridge is 22 miles N.E. of Arbigland, and at it there was at one time worked a thick limestone bed, and in the shale on top of it the prevailing coral is a *Lithostrotion* of the *Portlocki* type.

This type of coral at Arbigland is common on both sides of the syncline, so that if this limestone exists in the later district it must have got broken up into thin bands by the time its equivalents, or contemporaneous strata, reached the Arbigland area.

The two genera of corals, *Palastræa* and *Phillipsastræa*, occur at Blackwoodridge, but have not been got in the Arbigland rocks.

In the Arbigland strata no coal or bituminous shales were seen, but specimens of *Lepidodendron*, *Cordaites*, and *Stigmaria* were occasionally observed, all evidently drifted fragments.

Palæontology.

In 1869, in his paper on Southerness, our member, Mr. William Jolly, gives a list of fossils from the Arbigland rocks of thirty-nine species. He notes the abundance of the genus *Lithostrotion*.

The late James Thomson, in 1887, in his paper on *Lithostrotion* gives a list of fourteen species from Arbigland as

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belonging to that genus, besides mentioning the occurrence of other corals, and remarking on the scarcity of the rugose forms.

The Survey, in 1896, in their explanation to sheet 5, give a list of eighty-one species (for sheet 6, Arbigland), all of which they refer to the Calciferous Sandstone Series.

During an examination of the Arbigland rocks* ten species of fossils were collected from the beds relegated to the Calciferous Series, and 213 species from those placed in the Lower Limestone Series. My reason for thinking that the beds below the Thirlstone Sandstone belong to the Calciferous Series is the presence in them of *Platyostomella*, a genus not found in the Lower Limestone Series, but common on some horizons in the Calciferous Series of Fife.

Prothyris has only before been got in Scotland in the Millstone Grit, and its occurrence in the Arbigland beds shows that this genus had a long time-range in the Carboniferous Limestone rocks.

Dr. Wheelton Hind, to whom I submitted the lamellibranchs, remarks that the fauna represents the highest limestone of the Midlands immediately below the Pendleside series.

During the Arbigland period the astræiform *Lithostrotions* attained their maximum of development, and this genus of corals being abundant in the limestone rocks of the Misgan Maeve, near Sligo, these rocks were probably coeval in time, although the Arbigland ones were evidently a shallow water group compared with those of the Misgan Maeve, and, if not, the Misgan Maeve rocks were deposited much further from land.

During the Arbigland period the rugose corals were only slightly represented in the Lower Limestone Series, and reached their full development in the higher beds of that series in the West of Scotland, becoming well-nigh extinct by the time the Upper Limestone Series was laid down.

The sponge, *Pulvilus thomsoni*, appears to be a form not yet found out of the Southerness and Arbigland areas.

*Made by Mr. Robert Dunlop, Mr. James Wright, jun., of Kirkcaldy, Mr. James Neilson, Mr. James L. Begg, and the writer; the area of the collecting ground being about 50 acres, all tidal.

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A Stromatoporoid occurs in the Arbigland rocks, and I have only once before seen a Stromatoporoid in the Carboniferous strata. It occurred in the Upper Limestone of Ayrshire at Bowertrapping, a straggler from the lower regions.

Crustacea, cephalopods, and fishes are rare; lamellibranchs, abundant; brachiopods, common; and gasteropods, fairly well represented.

The conditions for the growth and preservation of seaweeds were better here than at any other part of the Carboniferous rocks, the equivalent of our present-day Laminarian Zone having occurred again and again, especially towards the lower part of the series.

Of the astræiform *Lithostrotions* got at Arbigland ten species have been made by the late James Thomson, but, although in the greatest perfection as to preservation, not more than three or four varieties can be deciphered by the ordinary individual, they so run into and get mixed, as it were (Plates V. to VIII.), with one another, and any person trying to reduce them by an "at-home" study might end in adding other ten to the number, which is not desirable. The late James Thomson was our greatest authority on corals, and among the last papers he wrote occur the following concluding remarks on the genus *Lithostrotion*:—"It will thus be apparent that amongst the species of this genus there are structural details of an extremely diverse character, including species which illustrate their polymorphic tendencies, and indicate that variation is so persistent that in tracing by means of these minute transitions there is no limit to the natural tendency to evolve from and to merge into both allied genera and species; inducing us to realise that in Nature there is no hard and fast line, that specific distinction is merely a temporary convenience, that varieties are the universal expression of both organic and inorganic matter." The visitor who spends a month at Arbigland and tries to diagnose the different corals he examines is very glad to find relief in saying "amen" to James Thomson's crowning sentence on the *Lithostrotions*.*

* The appalling catastrophe which has fallen upon Thomson's corals in the Kilmarnock Museum will send a thrill of regret around the whole world.

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Arbigland Fossils.

The following table shows the comparative abundance of the various orders of fossils in the Arbigland rocks:—

Plantæ,	Sea Weeds,	3
	Land Plants,	3
Spongida,		2
Stromatoporoidea,		1
Actinozoa,		39
Turbellaria,		1
Annelida,		3
Echinodermata,		3
Crustacea,		6
Polyzoa,		7
Brachiopoda,		36
Lamellibranchiata,		56
Gasteropoda,		25
Heteropoda,		7
Pteropoda,		1
Cephalopoda,		11
Pisces,		1
Tracks,		3
Burrows,	Vertical,	1
	Horizontal,	2
	Open,	2

Relationship of the Strata.

At Kelhead, 2 miles N.E. of Cummertrees station and 8½ miles N.E. of Arbigland, limestone has been extensively worked, and three beds are at present being quarried with an aggregate thickness of over 30 feet, the dividing shale below the upper bed being mottled red and grey, with great roots of *Stigmaria* in position of growth; the shale under the middle limestone is red. Fossils are scarce in the shales, but occasional corals are got, and *Productus giganteus* is not uncommon. The *Productus giganteus* of Arbigland differs from that shell at Kelhead, and these, again, from those of the Lower Limestone Series of Ayrshire. The Arbigland ones are the most primitive-looking; the Kelhead ones occupy a middle position as to development, and the Ayrshire ones by far the most perfect, and, having attained that state, they, like good aristocrats, died out.*

* *Productus giganteus* has been recorded from the Upper Limestone Series of Ayrshire, and I used to think it occurred on that horizon, but closer inspection has shown that what I took for small examples of *Productus giganteus* turned out to be extra large specimens of *Productus latissimus*.

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From this it looks as if the Kelhead beds occupy a middle position between the strata of Arbigland and those of the Lower Limestone Series of the West of Scotland.

The straight cephalopods reach their climax as to size at Kelhead and so link these strata with those at Closeburn, where large cephalopods were also got. One specimen of *Actinoceras giganteus* I measured is 10 inches in diameter, and must have been several yards long when in a living state. *A. giganteus* was a long-lived species, occurs at Arbigland and in the Upper Limestone Series of Ayrshire.

Gyracanthus occurs in the shales at Kelhead, so that this genus of fishes had a long time-range in the Carboniferous rocks—Lower Limestones to Coal Measures.

The following is probably the relationship in which the Arbigland strata stand to other Carboniferous rocks in Scotland:—

Reading downwards—

5. Lower Limestone Series, Ayrshire.

4. Limestone series of Kelhead, Kirtlebridge, Closeburn, and Blackwoodridge.

3. Arbigland, Upper

2. Arbigland, Lower (Calciferous).

1. Conglomerates, boulder beds, sandstones, mudstones, red and grey limestones, Mersehead to White Port.

Conclusion.

The five inliers of Carboniferous rocks forming detached fringes along the Solway from White Port to Mersehead, a distance of 18 miles, are made up largely of coarse sediments and conglomerates, some of them being basal conglomerates resting on the upturned edges of Silurian strata and on granite, so that, as pointed out by the officers of the Survey, the granite of the Criffel-Dalbeattie mass had been exposed at the surface before the Carboniferous period. We would naturally expect them to occupy a lower position than that of the Calciferous of the Thirlstone shore, and possibly they do, but every fossil from them links them on to the Lower Limestone Series. In fact, the Calciferous in this district hangs

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solely on the presence in it of one shell—*Platyostomella*—so that the word Calciferous may be wiped out so far as the Lower Carboniferous rocks of the Solway are concerned.

The boulder beds and their irregular stratification at N. end of Barlocco Heugh would seem to point to a period of cold when part of the strata were deposited from floating ice.

In the Calciferous division of the Arbigland strata there are occasional bands which have had a fresh-water origin, but no part can be compared strictly with the typical fresh-water cement-stones of Ballagan, Heads of Ayr, Whitadder of Duns, or the Berwick coast; nor with the sandstones of that series, if we except the Thirlstone bed.

In the Calciferous Series in Ayrshire not a single marine fossil has ever been found, but on the opposite side of the country, in Fife, marine bands occur repeatedly in that series, so that if we are to regard the strata in the five fringes from White Port to Mersehead as of Calciferous age they agree (so far) with those of Fife in having occasional marine bands, but it must be distinctly understood that not a single characteristic Calciferous fossil has yet been found in them.

Although the genus *Myalina* (*Naiadites*) is represented in the Arbigland rocks, no "*Myalina* limestones"—that is, beds almost entirely composed of these shells—occur, or at least were observed, such as are seen in the Calciferous strata of the Fife coast.

The upper Arbigland strata cannot be separated palæontologically on the one hand from the White Port to Mersehead rocks (probably on a lower horizon), nor on the other hand from the Lower Limestone Series of the West of Scotland (evidently on a higher horizon), but apparently must be relegated to the lower part of the latter, and were probably laid down when the lavas of the Dalry and Kilbirnie Hills were being poured out.

Solway Pits.

From the persistent and often steep dip of the Lower Carboniferous strata towards the Firth it is most likely that coal occurs under the Solway at a workable distance from the coast. Vertical pits sunk near the shore at the base of Wall

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Hill, Rerwick Park, Orroland, Barlocco, Rascarrel, Glenstocking, and between Portowarren and Portling, and mines driven towards the Firth would very likely reach the coal at no great distance.

TABLE SHOWING VERTICAL RANGE OF THE ARBIGLAND CARBONIFEROUS FOSSILS IN THE WEST OF SCOTLAND.

c = common. *f* = frequent. *s* = scarce. *r* = rare.

	Solway.	West of Scotland.			
	Arbigland.	Lower Limestones.	Ironstones.	Index Limestone.	Upper Limestones.
PLANTÆ.					
Land plants—					
Stigmaria,	r				
Lepidodendron,	r				
Cordaites,	r				
Seaweeds—					
Chondrites antiquus,*	c				
,, *gracilior*,*	c				
Laminaria?	f				
SPONGIDÆ.					
Pulvilus thomsoni,	f				
Clionoida arbiglandensis, n. sp.	f				
Cliona kelheadensis, new sp. Kelhead,	r				
STROMATOPOROIDEA.					
A Stromatoporoid,	r				r
ACTINOZOA.					
Cyathophyllum giganteum,	r	f			
,, *expansum*,	r	f			
,, *paracida*,	r	f			
Zaphrentis cylindrica,	f	f			
,, *spinulosa*,	r	f			
,, *centralis*,	r	r			

* Dr. R. Kidston informs me that these fossils are not now considered to be plants by some palæontologists.

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	Solway.	West of Scotland.			
	Arbigland.	Lower Limestones.	Ironstones.	Index Limestone.	Upper Limestones.
Actinozoa—*continued.*					
Cyathaxonia armstrongi,	r	r			
Dibunophyllum concinnum,	r	r			
,, *laticeptum*,	r	r			
Clisiophyllum turbinatum,	r	c			
Lithostrotion canadense,	r				
,, *maccoyianum*,	r	r			
,, *portlocki*,	c				
,, *aranea*,	c	r			
,, *basaltiforme*,	c	r			
,, *(Lithodendron)*,					
,, *martini*,	f	r			
,, *phillipsi*,	s	r			
,, *fasciculatum*,	f	f			
,, *affine*,	s	r			
,, *irregulare*,	c	c			
,, *junceum*,	c	f			
Michelinia tenuisepta,	r	s			
,, *favosa*,	r	r			
,, *megastoma*,	r				
Heterophyllia mirabilis,	r	c			
Stenopora tumida,	c	c			
,, *aff. urei* (hollow form),	r				
Monticulipora inflata,	c				
Syringopora gigantea,	r	r			
,, *geniculata*,	f				
,, *ramulosa*,	c	r			
,, *distans*,	f				
,, *laxa*,	r				
Aulopora gigantea,	r				
,, *gracilis*,	r	r			
,, *complanata*,	r				
Cladochonus giganteus,	r				
,, *crassus*,	r				
,, *bacillaris*,	r				
Turbellaria.					
Serpentaria problematica, n. sp.,	r				
Annelida.					
Spirorbis caperatus,	r	c			
Serpulites membranacea,	r				
Sabelloida gregaria, n. sp.,	c				

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	Solway.	West of Scotland.			
	Arbigland.	Lower Limestones.	Ironstones.	Index Limestone.	Upper Limestones.
Echinodermata.					
Poteriocrinus crassus,	f	c		c	c
Actinocrinus,	f				
Archæocidaris urei,	f	c	r	c	c
Crustacea.					
Bairdia brevis,	r	c			
Leperditia okeni,	f	c		c	
Cytherella valida,	r				
,, *tatei*,	r				
,, *recta*,	r				r
Phillipsia,	r				
Polyzoa.					
Ceriopora similis,	r	c		c	c
Rhabdomeson gracile,	f	c			s
Diastopora megastoma,	f	c		c	f
Glauconome elegans,	f	c			
Sulcoretipora robertsoni,	f	c			
Fenestella pleibeia,	c	c		c	c
,, *tenuifila*,	r	c			
Brachiopoda.					
Spirifera pinguis,	r				r
,, *trigonalis*,	r	c	s		c
,, *(Martinia) glabra*,	c	f			r
,, cf. *Mosquensis*,	r				
,, *(Reticularia) lineata*,	f	c			f
,, *ovalis*,	r	f			
,, *triradialis*,	r	f			
,, *cuspidata** (small),	r				
Spiriferina (Syringothyris) octoplicata,	s	f			
,, *laminosa*,	s	r			
Chonetes hardrensis,	f	c		c	c
,, *poleita*,	r	c			
Productus giganteus,	c	c			
,, *hemisphericus*,	s				
,, *scoticus*,	s	c			c
,, *martini*,	c	c			f

*** The Arbigland specimens are much smaller than those of Southerness.**

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	Solway.	West of Scotland.			
	Arbigland.	Lower Limestones.	Ironstones.	Index Limestone.	Upper Limestones.
Brachiopoda—*continued.*					
Productus scabriculus,	c	c			c
,, *costatus,*	r	s			c
,, *cora,*	c	c			c
,, *punctatus,*	c	c			s
,, *elegans,*	c	c			
,, *fimbriatus,*	c	c			
,, *undatus,*	r				r
,, *longispinus,*	c	c	f	c	c
Orthotetes crenistria (tumid var.),	r				r
Lingula mytiloides,	r	c	c		f
Rhynchonella (Pugnus) pleurodon,	c	c	s		c
,, ,, *pugnus,*	c	c			c
,, ,, *triangularis,*	r				
Terebratula (Dielasma) hastata,	c	c			c
Discina nitida,	s	c	s	c	c
Crania quadrata,	f	s		r	r
Athyris ambigua,	f	c		c	c
,, *planosulcata,*	s				
,, *(Cliothyris) royssii,*	s	c			
Camarophoria crumena,	s	s			
Lamellibranchiata.					
Actinopteria persulcata,	s	s			s
,, *concavus,*	r				
,, *granosus,*	r				
Pterinopecten radiatus,	s	s			
,, *meleagrinoides,* (?)	r				
Pinna flabelliformis,	s	c	s		s
,, *mutica,*	s	s			
Syncyclonema sowerbyi,	r	r			r
Pseudamusium concentricum,	f	f			f
,, *redesdalense,*	f				
,, *anisotum,*	s	s			s
Liopteria laminosa,	s	s			s
,, *lunulata,*	s	s			s
Pteronites angustatus,	r				
Aviculopecten semicostatus,	s				
,, *interstitialis,*	r				
,, *clathratus,*	s				s
,, *pera,*	s				
,, *tabulatus,*	r				
,, *murchisoni,*	f				s
Palæolima simplex,	r	r			
Limatulina scotica?	r	r			r

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	Solway.	West of Scotland.			
	Arbigland.	Lower Limestones.	Ironstones.	Index Limestone.	Upper Limestones.
Lamellibranchiata—*continued*.					
Limatulina desquamata,	r				
,, *alternata*,	r				
Myalina verneuillii,	s	s	s		s
,, *flemingi*,	f	f			f
,, *pernoides*,	f				
Naiadites crassa,	r	c	f		
Edmondia senilis,	r				
,, *rudis*,	r	c		r	r
,, *sulcata*,	r	f	s		
,, *maccoyi*,	r	r			
,, *arcuata*,	r	r			
,, *unioniformis*,	r				
,, *transversa*,	r				
Protochinodus obliquus,	s	r			
,, *axiniformis*,	f	s	s	s	s
,, *impressus*,	s				s
Prothyris elegans,	r				
Modiola emaciata,	r	r			
Lithodomus lingualis,	r	r			
Solenomya excisa,	r	r			
,, *costellata*,	r				
Sedgwickia ovata,	r				
,, *scotica*,	r				
Ctenodonta brevirostris,	r	r			f
Nucula gibbosa,	r	r	s		c
Nucullana attenuata,	r				
Grammatodon obtusus,	r				
,, *semicostatus*,	r				
Sanguinolites striatolamellosus,	s	s	s		s
,, *plicatus*,	s		s		s
,, *tricostatus*,	s	s	s		
,, *contortus*,	r				
,, *angustatus*,	r				
,, *clavatus*,	r				
(*Conocardium alatum*, Orroland),		r			
Gasteropoda.					
Naticopsis variata,	c	c	s		c
,, *plicistra*,	r	r	s		r
,, *elongata*,	r	r			
,, *omaliana*,	r				
,, *elegans*,	r				
Euomphalus pentangulatus,	c	r	r		r
,, *tabulatus*,	r				r

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	Solway.	West of Scotland.			
	Arbigland.	Lower Limestones.	Ironstones.	Index Limestone.	Upper Limestones.
Gasteropoda—*continued.*					
Euomphalus serpens,	r				r
,, *æqualis*,	r				
Murchisonia quadricarinata,	c	c	s		r
,, *striatula*,	r			c	r
Loxonema rottata,	r				
,, *rugifera*,	r	f			
,, *elongata*,	r				
,, *constricta*,	r	r			
Porcellia armata,	r	r			r
Strobeus lepidus,	r	r			
Macrocheilus (Macrocheilina) acutus,	s	f	s	c	s
,, ,, *fusiformis*,	r			c	s
,, ,, *tumidus*,	r				r
(,, ,, *michotianus*, *Orroland*),			s	f	
Scalites fusiformis,	r				
Platyceras (Capalus) vetustus,	f	r			s
Dentalium (Entalis) cf. *priscum*,	r				s
,, ,, *ingens*,	r				
Pleurotomaria,	r	r			
Heteropoda.					
Bellerophon laveilleanus,	r				r
,, *tenuifacia*,	f			r	r
,, *hiulcus*,	r	f			
,, *costatus*,	r				
,, *(Bucania) striatus*,	r			c	f
,, *(Wagenella) dumonti*,	r			c	r
,, *(Euphemus) urei*,	r	r	s	c	c
Pteropoda.					
Conularia quadrisulcata,	r	r		r	r
Cephalopoda.					
Orthoceras undatum (sulcatum),	r	s	r	c	c
,, *attenuatum*,	s	s	s	c	f
,, *cylindricum*,	r	r	r		r
,, *aciculare*,	r				
Actinoceras giganteum,	r	r			r

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	Solway.	West of Scotland.			
	Arbigland.	Lower Limestones.	Ironstones.	Index Limestone.	Upper Limestones.
Cephalopoda—*continued.*					
Cyrtoceras gesneri,	r				r
,, *unguis*,	r				r
Nautilus (Stoboceras) sulcatus,	r	f	r		f
,, *globatus*,	r	r		c	r
Glyphioceras truncatum,	r				
Ephippioceras bilobatum,	r				
Pisces.					
Helodus planus,	r	r			
Tracks.					
Crossopodia scotica,	s				r
,, *embletoni*,	s				
A winding track $\frac{1}{16}''$ wide,	r				
Burrows.					
Corophioides polyupsilon,	r				
Plinthoderma,	r				
Enteromorpha,	r				
Nests or Open Burrows.					
Heughia gregaria, n. sp.,	c				
Circular nest,	f				

The following are new to Scotland :—

Lithostrotion canadense.
Michelinia megastoma.
Productus hemisphericus.
Aviculopecten pera.
Limatulina desquamata.
,, ***alternata.***
Pterinopecten meleagrinoides.
Edmondia senilis.
Grammatodon obtusus.
,, ***semicostatus.***
Sanguinolites contortus.
Glyphioceras truncatum.
Ephippioceras bilobatum.

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The following are new to Science :—

Clionoida arbiglandensis.
Cliona kelheadensis.
Heughia gregaria.
Sabelloida gregaria.
Serpentaria problematica.

Notes.—*Aulopora* and *Cladochonus* are by some Palæontologists thought to be young stages of *Syringopora*, but I have seen *Cladochonus* (frequently) where I have never seen *Syringopora*.

For a few of the horizons (Ayrshire) of some of the species I am indebted to the lists of the late Robert Craig, published by the Society in vols. v., vi., vii., viii.

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I am indebted to Mr. A. Macconnochie of the Survey for information bearing on the literature of the subject. The district was surveyed by Dr. John Horne.

EXPLANATION TO ILLUSTRATIONS.

Plate I., Fig. 1.—*Clionoida arbiglandensis*, new species.

They appear as shallow slits 2 mm. long by ·5 of a mm. wide on the surface of *Productus giganteus*, and extend into the shell but a short distance, their long axis being seldom in the direction of the ribbing, but mostly across it at varying angles. As many as twenty may occur on one shell. It also occurs sparingly on *Monticulipora inflata*. I have named it *C. arbiglandensis*, after the place where it occurs, and the burrows were probably made by a boring sponge.

Plate I., Fig. 2.—*Cliona kelheadensis*, new species.

These occur on the surface of a specimen of *Productus hemisphericus* 2 inches wide, and extend over the whole width of the shell. They ramify as shallow gutters on the surface of the shell, and descend here and there into its substance, averaging about $\frac{1}{10}$ of a mm. in width, but although the bulk of them now show on the surface there are strong indications that they were originally under it, the shell having been naturally etched. There is no generic difference between these minute burrows and those made by the sponge, *Cliona*, of our own seas, which burrows into the substance of shells, &c. The illustration is enlarged 4 diameters. I have named it *C. kelheadensis*, after the place where I found it.

Note.—On microscopical examination I could see no spicules in connection with any of the above burrows, Figs. 1 and 2.

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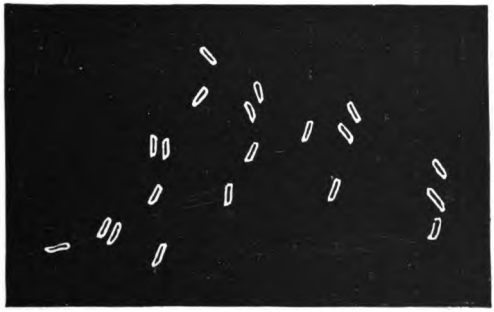

Fig. 1.—Clionoida arbiglandensis (nat. size).

Fig. 2.—Cliona kelheadensis (enlarged 4 diameters).

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Fig. 1—Heughia gregaria (nat. size).

Fig. 2.—Serpentaria problematica (nat. size).

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Fig. 1.—Sabelloida gregaria (nat. size); under side of slab.

Fig. 2.—Sabelloida gregaria (nat. size); upper side of slab.

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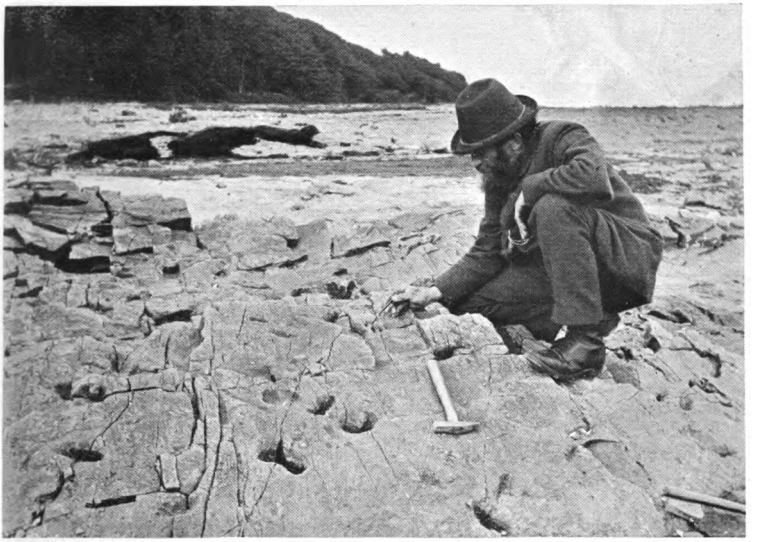

Fig. 1.—Corophioides polyupsilon.

Fig. 2.—Thirlstone Sandstone.

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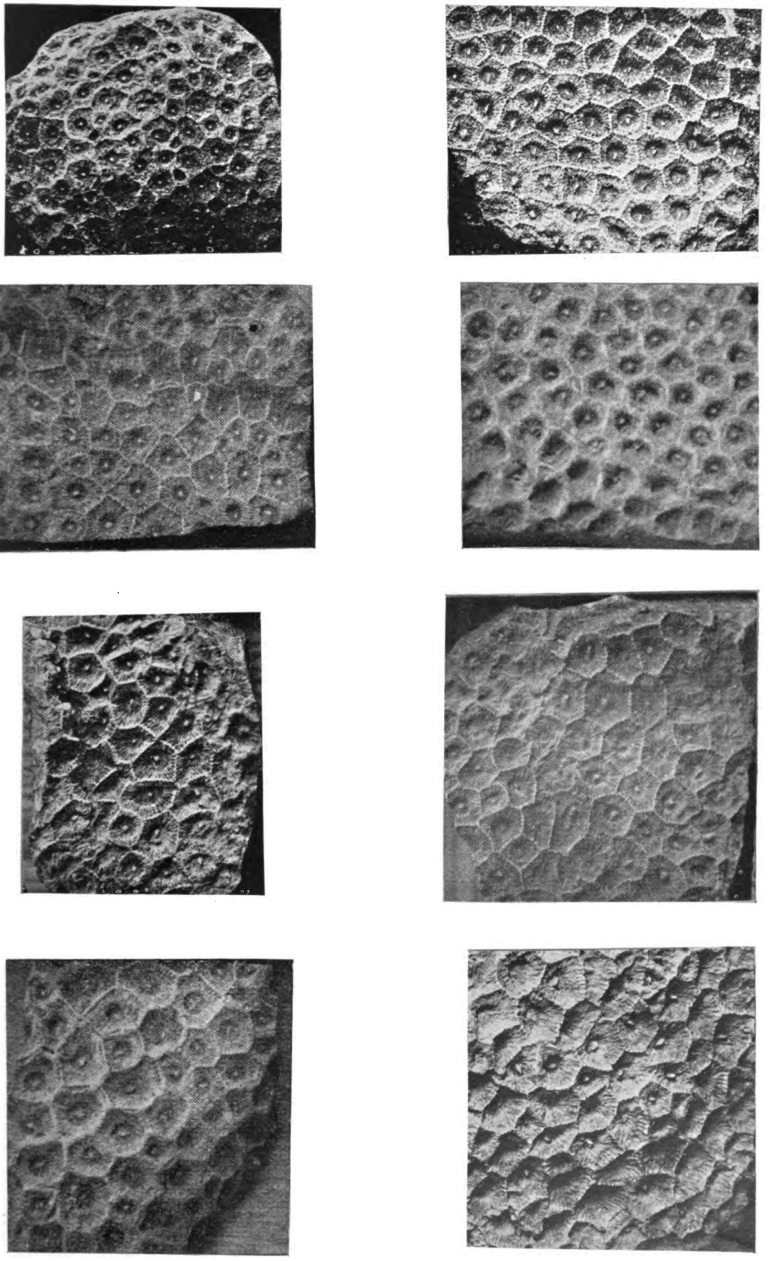

Astræiform Lithostrotions (nat. size).
(Illustrating paper by John Smith on "Rocks of the Solway.")

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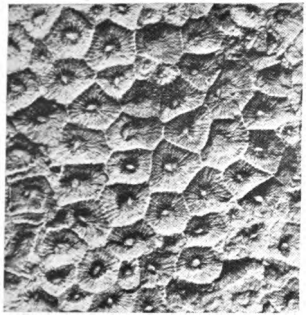

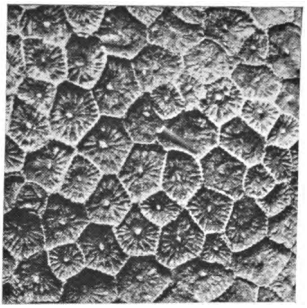

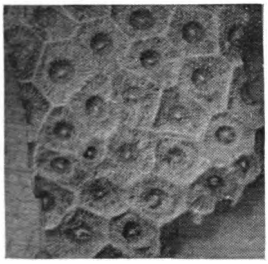

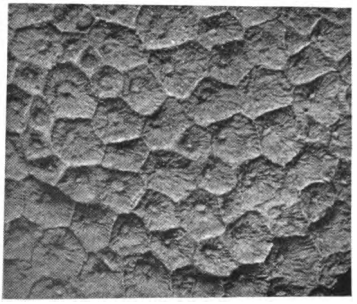

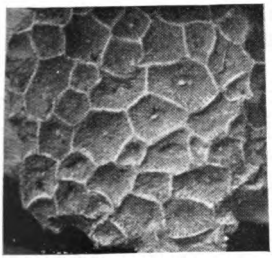

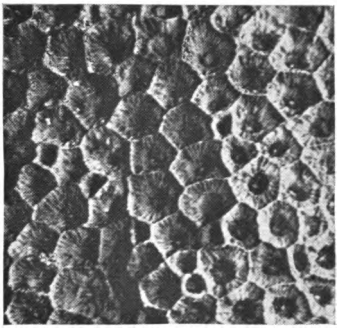

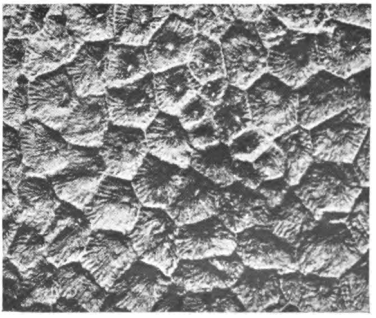

Astræiform Lithostrotions (nat. size).
(Illustrating paper by John Smith on "Rocks of the Solway.")

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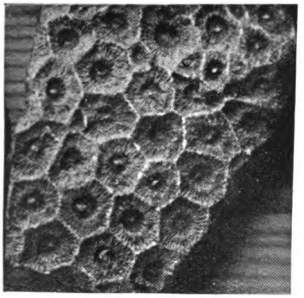
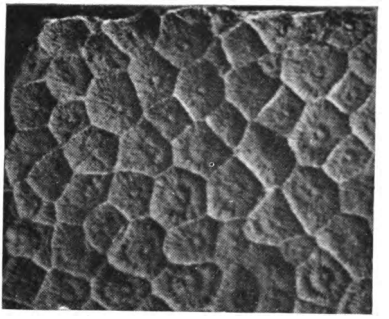
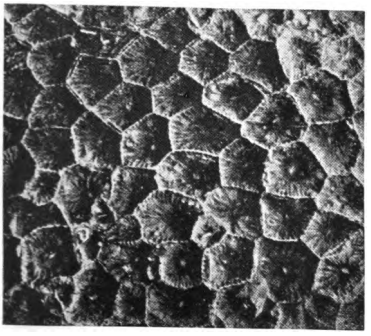
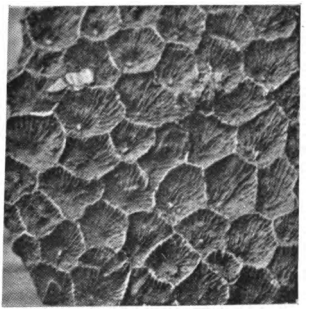
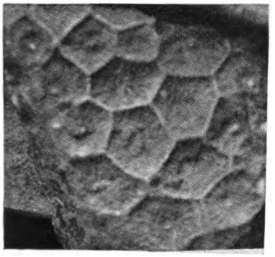
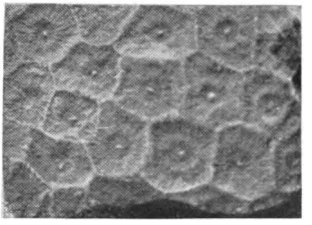
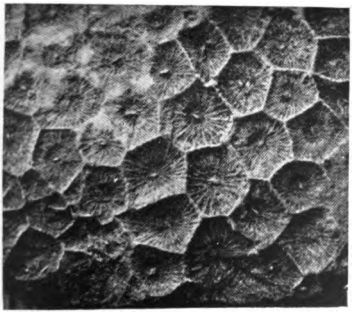
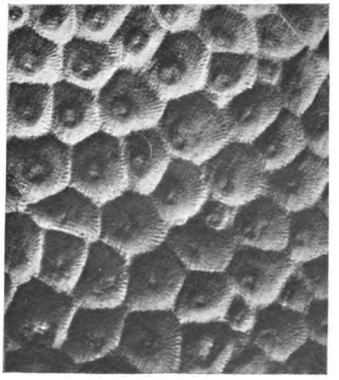

Astræiform Lithostrotions (nat. size).
(Illustrating paper by John Smith on "Rocks of the Solway.")

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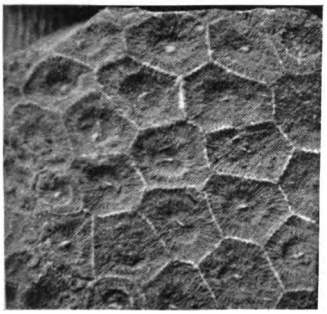

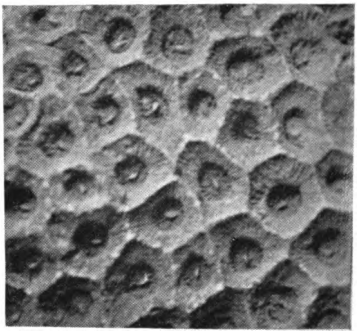

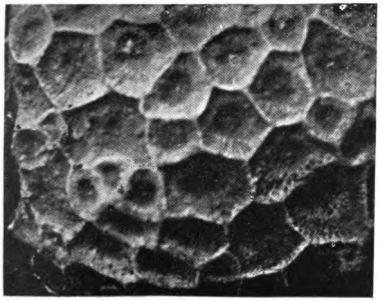

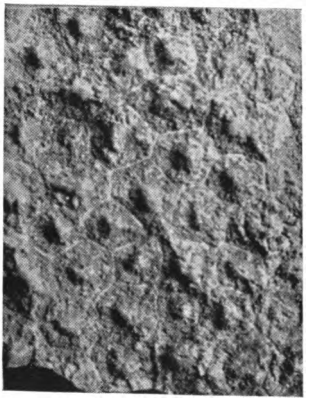

Astræiform Lithostrotions (nat. size).
(Illustrating paper by John Smith on "Rocks of the Solway.")

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Plate II., Fig. 1.—*Heughia gregaria*, new species, nat. size.

These open burrows or nests vary in size from ⅝ to 1⅛ inch long, and ¼ of an inch broad, more or less, by ¼ of an inch deep. They lie in every direction in the substance of a slab of sandy limestone, and occasionally run the one into the other. No footmarks or tracks are ever seen extending up to them, and they were evidently made by some kind of animal on the mud of the sea bottom. Locality, Arbigland.

Plate II., Fig. 2.—*Serpentaria problematica*, new species, nat. size.

I submitted this specimen to Mr. A. Macconnochie and Dr. Lee of the Survey, who think it may be the cast of a large worm. The alternative to this would be a winding burrow, or it might be an actual fossil of the print of an animal something like that of *Serpentaria* of our own seas, which is always seen to be coiled up much in the manner of this fossil. It is the only specimen I found, and might be called *Serpentaria problematica*.

Plate III., Figs. 1 and 2.—*Sabelloida gregaria*, new species, nat. size.

Tubes oval, strong; largest ones 5 by 4 mm. On one side of a ⅝-inch thick slab they are seen in cross section, a little open (Fig. 1), and on the other side they are lying down (Fig. 2), and extend to a little more than an inch in length, so that, originally, they have been stuck into the sand of the sea bottom with the greater part of the tube projecting. I have named it *Sabelloida gregaria*, from its resemblance to the tubes of the *Sabella* of our own seas, and it looks to have been a leathery pipe covered with sand and, perhaps, bits of shells, now decayed. Locality, Arbigland, crowding a thin layer of sandstone north of the "Crannog."

Plate IV., Fig. 1.—*Corophioides polyupsilon.*

This illustration shows a number of the washed-out burrows of *C. polyupsilon** which occur in the upper part of a bed of hard sandstone. The point of the pencil touches one of the upper ends of a tube, the other end will be seen a little to the left. The washed-out spaces are 4 inch by 3 inch, and 3 inch deep. Locality, Arbigland.

Plate IV., Fig. 2.—

Part of the Thirlstone Sandstone, showing some of the peculiar twistings.

Plates V., VI., VII., VIII.—Astræiform *Lithostrotions*, nat. size.

Showing a graduated series from the smallest to the largest. The last three figures on Plate VII. are taken from weathered specimens showing central projecting bosses. Locality, Arbigland.

Note.—I am indebted for the photographs for the plates to Mr. R. Dunlop, Mr. James Wright, jun., of Kirkcaldy, and Mr. S. M'Caughey, of Dalry.

* See *Trans.*, vol. ix.

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No. III.—The Fossil Amphibia in the Kilmarnock Museum Previous to the Fire of 1909. By Robert Dunlop.

[Read 10th March, 1910.]

Among the contents of this museum previous to the late disastrous fire were two large and celebrated collections of Scottish fossils. That of Dr. Hunter Selkirk, which included Scottish fossils from the Silurian up to the Carboniferous rocks, and that formed by Mr. James Thomson, which consisted mainly of Carboniferous fossils from the West of Scotland. These collections, along with several others, principal among which was that formed by the Rev. Dr. David Landsborough, were almost totally destroyed.

Previous to this fire the Kilmarnock Museum was among the foremost in the country as regards the field of Scottish Palæontology, and it is safe to say that a thorough grasp of the subject could not be had without a knowledge of its contents. It was exceptionally rich in certain groups, and more especially in Carboniferous corals, containing as it did the large collection of these organisms formed by Mr. Thomson, and including nearly all his types, not to speak of the beautiful amphibian remains which he was fortunate enough to obtain. The loss of these leaves sad gaps, which may not again be filled, as economic changes in our country, and the working out of many of the mineral seams concerned, render the replacement of these specimens a matter of extreme doubt.

The present paper is intended to be an "In Memoriam" notice of the Carboniferous Amphibia in the collection of the late Mr. James Thomson, F.G.S., while at the same time including a few words on the subject in general.

So far as we know the remains of Amphibia appear first in strata of Lower Carboniferous age, in which, however, they are comparatively rare and mostly fragmentary. These ancient Amphibia belong, all of them, to one extinct order, that of the Stegocephalia, or "roof-headed" Amphibia, which ranged upwards as far as and including the Trias; indeed, so far as size is concerned, they reached their maximum in the great

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Mastodonsauri and *Capitosauri* of that formation. The larger members of this order are usually termed "Labyrinthodontia," from the complex "labyrinthic" folding of the dentine or tooth substance at the basal portion of the teeth. In Smith Woodward and Sherborn's catalogue of British fossil vertebrata the Stegocephalia are represented by thirty-one species, comprised in twenty-two genera, of which twenty-two species and sixteen genera are from Carboniferous rocks. And so far as Carboniferous Amphibia are concerned, I have not seen any in the British Museum, or others which I have visited, that excelled or even equalled in beauty those in the Thomson collection.

The first discovery of amphibian remains in the Carboniferous rocks of the West of Scotland was made about the year 1862 by Mr. James Russell of Chapelhall, who took a skull, which he had found in the ironstone of Palacecraig, near Airdrie, to London, and showed it to Professor Huxley, through whose advice it was purchased for the Museum of Practical Geology, Jermyn Street. This skull was afterwards described and figured by Huxley under the name of *Anthracosaurus russelli* (*Quart. Journ. Geol. Soc.*, vol. xix., p. 56).

This naturally excited much interest among the young geologists and collectors resident at that time in Glasgow, and among whom were included Thomson, Young, Armstrong, Hunter, and others. Among these James Thomson was by far the most successful in obtaining amphibian remains, partly on account of his own indefatigable industry, but even more so because he succeeded in obtaining a unique collection of these fossils formed by an intelligent miner named Cameron, who worked near Quarter in an ironstone seam known as the "Airdrie" or "Mushet Blackband." Now, in this locality the seam in question had become divided into two parts with a thin layer of coal between, and it was in this coal that the remains were found, a fact which rendered their disinterment more easy than it would have been had one had to deal with ironstone alone.

When it became known, about the year 1867-68, that this collection might be acquired, a race for its possession took place between Mr. Thomson and Dr. Hunter Selkirk, and the former

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gentleman had hardly secured it when the latter appeared on the scene.

This was by far the finest collection of these remains which had ever been made in Scotland, and when added to the specimens which he himself had previously obtained it rendered the Thomson collection of Carboniferous Amphibia the finest perhaps in Britain.

The "Cameron" specimens were exhibited at the meeting of the British Association in Glasgow in 1868, and in 1869 a new genus, *Megalerpeton*, containing two new species, *M. simplex* and *M. placidens*, was founded by Professor J. Young and Mr. Thomson on specimens contained in this collection.

In Mr. Thomson's collection there were no fewer than six skulls, either complete or nearly so, besides detached jaws, ribs, teeth, and other relics. These filled six drawers in his cabinet, and when a kindred spirit visited his house for the first time he almost invariably showed this part of his collection first.

In this connection, next in importance to the Quarter Blackband comes the Palacecraig Blackband, which was worked at Palacecraig and Carnbroe in the Airdrie district.

When I first visited Palacecraig in the early seventies not much was turning up, as the pit was almost worked out, but I learned from the workmen that Thomson was well known there, and had been in the constant habit of visiting the pit on Saturdays, wet or fair, and that he also regularly visited Carnbroe, where he secured some very fine fish remains.

Airdrie and Quarter were, however, not the only places in Scotland where Carboniferous amphibian remains have turned up, as remains, supposed to be referable to this class of vertebrates, have been recorded from different localities in the neighbourhood of Glasgow. One of the most interesting of these "finds" was a specimen in the Kilmarnock Museum, collected by Mr. Linton, of Kilmaurs, in the Annick Lodge shale beds, and familiarly known to the geologists of the west as the "Fossil Monkey." This was a vertebral column, 31 inches in length, in which twenty-eight distinct vertebræ and twelve ribs could be counted—about one-half were complete and in

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position—and the whole specimen was so nicely developed by Mr. Linton that the vertebræ and ribs stood out in relief. A large amount of the Annick Lodge shale remains still to be worked, so the chance may yet come to make a good collection of the Carboniferous Amphibia of Ayrshire.

Amphibian remains have also turned up in ironstones of Lower Carboniferous age in the East of Scotland, as at Loanhead and Gilmerton, near Edinburgh. Some specimens from the former locality were in Dr. Hunter Selkirk's collection, including an incomplete skull (*Anthracosaurus?*), and some detached and fragmentary jaws and other bones.

In the British Association "Handbook," Glasgow, 1901, the late Professor J. Young enumerates five genera and six species of Labyrinthodont Amphibia from the Carboniferous strata of the West of Scotland, namely—

	Localities.	Loc. of Type.
Anthracosaurus russelli (Huxley),	Airdrie and Quarter.	Palacecraig, Airdrie.
Loxomma allmani ,,	Carluke, Palacecraig.	Gilmerton, near Edinburgh.
Megalerpeton placidens (Young & Thomson),	Quarter.	Quarter.
,, *simplex* ,,	,,	,,
Pholaderpeton sp.,	Quarter, Palacecraig.	Toftsham, near Bradford, Yorks.
Pteroplax cornuta (Hancock & Athey),	Quarter, Raesgill.	Newham, Northumberland.

Besides the specimens already alluded to, Mr. Thomson's collection contained many others of interest. There was a jaw of the so-called *Rhizodus lanceiformis* (*Loxomma*, 9½ inches in length by 2 in width), showing nine perfect teeth and four imperfect teeth, with the stumps of seven others. There were also pieces of slabs of ironstone and coal showing vertebræ and ribs, as well as numerous other bones and dermal scutes.

The ironstone at Quarter in which Mr. Thomson's specimens were found lay 40 fathoms below the surface, the section consisting of ironstone, shale, and coal. The remains were found on the surface of the coal, covered by the superincumbent ironstone, and were extremely well preserved. This ironstone may be said to be the equivalent of the Airdrie or

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Mushet Blackband, which also crops out in the river Avon. According to Mr. Ralph Moore's published section, it lies about 564 feet below the uppermost Coal Measures, and 646 feet above the Moorstone Rock, while probably 2000 feet or more intervene between it and the horizon of the Burdiehouse Limestone in the Edinburgh district.

The Palacecraig Ironstone, in which the amphibian remains were found near Airdrie, is the highest workable band in the Lanarkshire coalfield, being situated about 34 fathoms above the "Ell coal." So far as observation has gone hitherto, these remains seem in the West of Scotland to be confined to strata of fresh-water or estuarine origin, and they range from the Lower Limestone Series to the higher beds of the Coal Measures.

It is to be hoped that some at least of these interesting remains which were in the Kilmarnock Museum may yet be recovered from the ashes of that disastrous fire in which so much has been lost to Palæontological science.*

In conclusion, I have to thank my friend Dr. R. H. Traquair, M.D., F.R.S., for looking over and making corrections on my paper, on the subject of which he is so well able to speak.

Note.—See paper on "Footprints in Red Calciferous Sandstones in railway cutting 2¼ miles north of West Kilbride," by John Smith. *Trans. Geol. Soc. of Glasgow*, vol. ix. p. 201.

EXPLANATION OF PLATES.

Plate IX., Fig. 1.—The head of *Anthracosaurus* (Airdrie or Mushet Blackband, Quarter), measuring 10 inches long by 8 inches in width. Posteriorly opposite the vomerine tusk it is 4 inches wide, the underside being turned upwards, exposing the stumps of forty broken teeth around its contour. On the same slab, and partly resting on the posterior of the skull, there is an under jaw with the anterior face thrown backwards, and which probably belongs to the same animal.

Plate IX., Fig. 2.—Head of *Loxomma allmani*.

Plate X., Fig. 1.—A jaw from the same locality (Quarter), measuring 12½ inches long by 4 inches wide at the widest part, with seven perfect teeth and the stumps of eighteen exposed.

Plate X., Fig. 2.—Jaw of *Pteroplax* (?).

Plate X., Fig. 3.—Vertebræ and ribs of the Amphibian found at Annick Lodge by R. Linton.

* A considerable proportion of this valuable group of fossils has been recovered from the débris, though in a fragmentary condition.

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Fig. 1.

Fig. 2.

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Fig. 1.

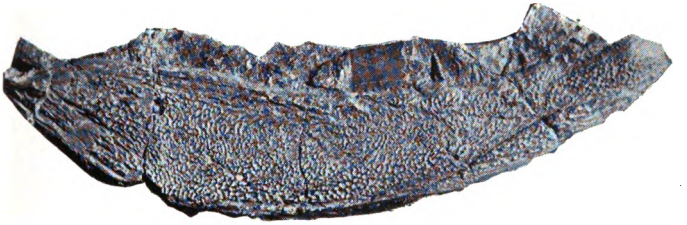

Fig. 2.

Fig. 3.

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No. IV.—On Zonal Work in Lower Carboniferous Rocks, with some Remarks on the Collection of Fossils.

By R. G. Carruthers, F.G.S., of H.M. Geological Survey.

[Read 6th December, 1909.]

The subject of this communication has already been brought before the Society by Mr. James Neilson.* Still, even when considered from a purely zonal standpoint, Carboniferous palæontology is inevitably associated with so many side issues that a further review of the present state of affairs may not be unwelcome.

In the British Isles zonal work on the Lower Carboniferous rocks is based entirely on the researches of Dr. Arthur Vaughan; and rightly so, for they bid fair to resolve a problem which, only a few years ago, was thought to be practically incapable of solution. Yet it should not be forgotten that Belgian geologists initiated the zoning of the Carboniferous Limestone many years ago. The basis of the Belgian scheme was comprehensive in nature; fishes, cephalopods, brachiopods, and corals were all utilised, besides a certain amount of purely lithological data. The zones thereby established were ill-defined and somewhat unsatisfactory. One result, however, was made clear; the limestone was divided into an upper part, termed Visean, and a lower part, called Tournaisian; (at first a middle or Waulsortian division was also recognised, but this is now regarded as a special phase of the Visean).

These two great divisions have been recognised in several European countries, and have proved of considerable use to stratigraphers. Where originally investigated, that is to say, in Belgium itself and in north-eastern France, their exact relationship to each other is, unfortunately, obscure. The conformable passage of the Tournaisian down into the Upper Devonian can be demonstrated, and also the passage of the Visean up into Upper Carboniferous strata, but the actual

* Article on "Review of Fifty Years' Work: Palæontology," in the "History of the Geological Society of Glasgow," pp. 139-164. (1908.)

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junction between the Tournaisian and Visean themselves has apparently not been observed. It is not yet clear, therefore, whether an interval of time elapsed between their deposition or whether they are partly equivalent, the faunal differences arising in some degree from the effect of distinctive physical conditions in the two provinces.

As far as England is concerned, Belgian geologists were able to recognise a full sequence of their zones in the Avon gorge, near Bristol, and they were also of opinion that in north-west Yorkshire an enormous overlap occurs, so that on Ingleborough Visean strata rested directly on pre-Carboniferous rocks; their conclusions, however, for long remained almost unknown to British geologists.

Dr. Vaughan's work, although of much later date, was of an entirely independent character. His scheme, in which brachiopods and corals alone were used, was originally drawn up from data obtained in the gorge of the river Avon, near Bristol. At this locality the whole of the Carboniferous Limestone, from the conformable junction with the Old Red Sandstone right up to the Millstone Grit, is displayed in one continuous series of magnificent cliff sections. Observations subsequently made have resulted in the addition of two other zones or sub-zones (D_3 and P) cut out in the Avon section by the Millstone Grit.

As now established, there are six main zones, divided in turn into sub-zones, and separated by passage beds possessing subzonal value. The full sequence is outlined in tabular form on the opposite page, a few of the more important and characteristic fossils being given with each subdivision; the reader should, however, consult the original paper for fuller details.

Following the application of this zonal scheme in England, Wales, and Ireland, the main zonal succession has not only been found to hold good to a remarkable extent, but stratigraphical features of the first importance have been discovered whose existence had previously been unsuspected. We have, for instance, the demonstration of a strong unconformity within the Limestone itself in South Wales, and of the Upper Visean age of the Derbyshire massif. The suggestion by Belgian geologists that the whole of the Tournaisian is cut out by

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overlap in north-west Yorkshire has been independently confirmed, and a similar overlap has also been discovered in North Wales. Finally, in the far west of Ireland, the great limestone tablelands of County Clare have revealed a complete zonal sequence, differing but slightly from that found in the Bristol district itself.

Deductions such as these have widened our knowledge of Carboniferous stratigraphy in a very remarkable degree, and they have followed Dr. Vaughan's original paper so rapidly that one is apt to forget how hopeless the outlook for zonal work appeared only a few years ago. It is therefore all the more regrettable that difficulties of a special nature, hereafter detailed, attend an application of the scheme to Scottish strata.

OUTLINE SCHEME OF THE AVONIAN ZONES.

		ZONES.	SUB-ZONES.	CHARACTERISTIC FOSSILS.
Avonian.	Visean.	'Posidonomya' or P	Upper P	
			Middle P	
			Lower P	*Michelinia favositoides* — *Martinia ovaliglabra*
		'Dibunophyllum' or D	D_3	*Cyathaxonia rushiana*, *Productus scabriculus*
			D_2	*Dibunophyllum* ψ (? = *D. turbinatum*); *Cyathophyllum regium*; *Lonsdaleia floriformis*; *Productus giganteus*
			D_1	*Carcinophyllum* sp., *Chonetes* aff. *comoides*; *Dibunophyllum* θ, *Productus hemisphericus*
		'Seminula' or S	S_2	*Productus cora* [Dav.] mut. S_2
			S_1	*Lithostrotion basaltiforme*; *Productus semireticulatus*, mut. S_1 (spinose form)
			δ	
	Tournaisian.	'Caninia' or C		*Michelinia grandis*, *Syringothyris laminosa*; *Caninia gigantea*
		'Zaphrentis' or Z	γ	*Caninia cornucopiæ* — *Zaphrentis konincki*
			Z_2	*Zaphrentis omaliusi* — *Zaphrentis konincki*
			Z_1	*Zaphrentis delanouei* — *Cliothyris glabistria*
			β	
		'Cleistopora' or K	K_2	*Spirifera octoplicata* — *Cleistopora geometrica*
			K_1	*Productus bassus* — *Cleistopora geometrica*
			α	
		'Modiola' phase or M		*Cliothyris royssii*

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When reading Dr. Vaughan's original paper, one of the first criticisms to be made by those interested in the palæontology of the Scottish Carboniferous rocks is that the names of certain species familiar in our Carboniferous Limestone Series appear low down in the Tournaisian. At first sight it would seem, therefore, that these species have much greater vertical range with us than in extra-Scottish areas, for it has long been known that our Limestone Series must lie high in the Visean. And, as a matter of fact, the point has been noted by Mr. Neilson in the article referred to at the head of this paper. As far as this difficulty is concerned, however, it should not be forgotten that minute structural differences may be of great zonal importance, and that it by no means follows that the English and Scottish fossils are identical, although for the present the same name may be allotted to them.

A difficulty of greater moment lies in the fact that (at any rate, so far as the corals are concerned) the zones are not in continuous genetic sequence, so that the apparent range of most of the species does not represent the full length of their existence in the scheme of evolution, but depends rather on the duration of the particular physical conditions favourable to their existence. The fauna of each zone does not represent direct descendants from the immediately preceding zone, but usually marks an immigration of quite different stocks, brought in by a change of conditions. Further, any one gens (or group of closely related species) may recur, with little change, after a variable interval of time. During that interval the gens must have flourished elsewhere, so that we cannot say that the mere occurrence of the same species in two or more areas necessarily takes place in the same time-zone at each place.

These objections do not affect the value of the scheme when used in a broad sense, but are only pointed out as a caution when finer stratigraphical details are needed, or in correlating areas which are, geographically, far apart.

Again, in any two districts it may happen that at one and the same time conditions of existence were very different, and, in consequence, the faunal assemblages of these districts have little in common. It is for this very reason that an extension of the scheme to Scotland is hardly practicable at the present

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time. A brief consideration of the facts should make this apparent.

In the first place, the equivalents of most of the English zones lie, in Scotland, in the Calciferous Sandstone series, which (except in small areas along the Border) is to all intents and purposes barren of brachiopods and corals. But, this fact apart, even our most fossiliferous beds, in the Limestone Series, present great difficulties in zonal work, for the following reason:—The Upper and Lower Limestone Groups of Scotland (together comprising the Carboniferous Limestone Series) are known to be, broadly speaking, of Upper Visean age. The Lower Group has been traced by most careful field work down through the North of England into the Yoredale Limestones, which, near Ingleborough, overlie the main massif of the Carboniferous Limestone, still of Visean age.

Now, the corals and brachiopods of the two Scottish Limestone Groups, and also of the Yoredale rocks, belong to a particular faunal phase, which persists right up to the end of the Lower Carboniferous period (*i.e.*, up to the break in the Carboniferous flora and fishes that occurs in the Millstone Grit). But south of Ingleborough, and in Ireland also, wherever zonal work has been done, this particular faunal phase has only been found in the Upper *Dibunophyllum* (or D_2) sub-zone, and two totally different phases supervene before the upper limit of the Lower Carboniferous rocks is reached in the Millstone Grit. These new phases are represented in the *Cyathaxonia rushiana* (or D_3) and the *Posidonomya* (or P) sub-zones. In so far as the corals are concerned, it can be said that not one single species peculiar to the D_3 or P sub-zones has yet been found in the Scottish rocks.*

To sum up, therefore, the particular physical conditions favourable to the development of the D_2 phase, persisted in Scotland right on to the close of the Lower Carboniferous period; in the Midlands and in the south-west of England, and in Wales and Ireland, these conditions obtained for a comparatively short time, and were succeeded by others of a quite different kind. And although we know that our Car-

* James Thomson was mistaken in his identification of the genus *Cyathaxonia*. The genus, however, is known to occur in the Lower Limestone Group, but *C. rushiana* has not yet been definitely recognised, the cottish species being extremely close to the Tournaisian *C. cornu*.

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boniferous Limestone series must contain the time equivalents of the D_2, D_3, and P sub-zones, the faunal succession is so different in the two cases that comparative correlations are hardly practicable in the present state of our knowledge.

The necessity of obtaining the genetic range of species before their zonal value can be ascertained is, in my opinion, an essential matter. To illustrate the argument some concrete examples may be utilised. Take, for instance, such well-known fossils as *Productus latissimus* and *Nautilus nodiferus*. Most Scottish geologists use these fossils zonally, as indicative of Upper Limestone strata. But for what reason are they commonly found in the Upper Limestones only? Is it because they were not evolved until Upper Limestone times, or were they established previously, living in outside areas, until the onset of favourable physical conditions during the deposition of the Upper Limestone group allowed of their introduction to Scottish areas? If the latter cause be the true one, then it is clear that these species do not, after all, necessarily point to an Upper Limestone position, but may appear on lower horizons also. And, as a matter of fact, this is the case, for we know of typical specimens of *P. latissimus* in the Lower Limestone near Paisley, and of *Nautilus nodiferus* from the Lower Limestone (Hosie) beds of the East Kilbride basin.

Take, again, the case of those large cup corals, the Clisiophyllids. These are usually considered as characteristic of the Lower Limestones, and not to occur in the Upper Group. Yet they are extraordinarily abundant in the Upper Limestones at Bruntsfield Castle, Midlothian, and also near Linlithgow and Cumnock, where they differ but slightly, if at all, from those found in the Lower Limestones. Their limitation, in most parts of Scotland, to the Lower Group is quite evidently due to generally unfavourable conditions in Upper Limestone times, and to that cause only.

These cases may serve as illustrations of the inadvisability of taking the apparent restriction of fossils to one stratum (or group of strata) as an absolute fact until the reason is known. What is needed is the determination of the *genetic* range of each species, *i.e.*, the relative length of time that species flourished, from its inception to the decline and replacement by direct descendants. This genetic range must almost invariably

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be much longer than the range noted in any one district or locality. In Carboniferous times physical conditions were hardly ever so stable as to allow of a species passing through its whole evolutionary existence in one district without a temporary banishment to other regions. And as the causes that occasioned this banishment are not of necessity expressed lithologically (for instance, they may have arisen from slight changes in temperature), safety is only assured by taking the full genetic range of a species as its zone.

Zones based on genetic series are, of course, extremely difficult to obtain. One of the best examples is perhaps that afforded by Dr. Rowe's researches on the chalk sea urchins, belonging to the genus *Micraster*. In this case the various species of *Micraster* were collected at all horizons in the chalk, and arranged in one long evolutionary series; the varying characters assumed by each species from its rise to its fall were noted, and also the passage forms linking species to species. As a result, the exact genetic range of each form was determined, and not merely a range governed by the duration of the particular physical conditions favourable to that species. Now, all our experience supports the conclusion that evolutionary changes are of a synchronous nature over very wide areas. Consequently this work on the *Micraster* species has led to the establishment of an exact and genetic zonal scale, which has been applied to the Upper Cretaceous rocks with the greatest success.

Beyond doubt work of this nature has been greatly facilitated in both Cretaceous and Jurassic rocks by the long-continued prevalence of physical conditions favourable to one special form of life. It is well known that this was not the case in Lower Carboniferous times. Nevertheless, the immense difficulties thereby introduced are somewhat lessened in our Carboniferous Limestone series by the stratigraphical exactitude which has been attained therein. Although we cannot hope to obtain a long, vertical suite of any one gens from a single locality, we can at least build up such a suite by following the limestones from place to place until a good series of fossils has been collected. In this way the diversity of physical conditions, at first such a stumbling block, may actually be turned to advantage.

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I would suggest, therefore, that when collecting fossils for zonal purposes, large numbers of specimens should be gathered wherever possible. All the forms that centre round a particular species, or group of species, should be collected (*i.e.*, the specimens should belong to the same gens). The efforts of the collector should be turned towards the accumulation of a strictly average assemblage from each locality rather than the collection of abnormal or finely preserved material. Any limestone that appears to be barren of the particular gens sought for should, if possible, be followed into districts where it happens to be productive.

Assemblages obtained in this manner should be collected from every possible horizon and over as wide an area as possible. And, finally, each of these assemblages should be subjected to the closest scrutiny with the object of finding, if possible, some change of an evolutionary nature. Probably any such changes will be of slight amount, but every point should be noted in the hope that it may eventually prove of value. For instance, in the case of the brachiopods, both external characters (general shape of the shell, nature of ribbing, &c.) and internal characters (teeth, muscle markings, &c.) should be noted and any interrelationship observed; and similarly with the corals. Any arbitrary distinctions between species or varieties may be used, provided that the ultimate designation is, if need be, corrected before publication. This latter point should be attended to; modern palæontology is already sufficiently burdened by the necessity of changing names wrongly used by old writers, without adding modern authors to the list.

As already mentioned, it is probable that any evolutionary changes observed will not only be of slight amount, but will take place with extreme slowness. Consequently the genetic range of each species in a gens may be of considerable extent. Nevertheless, by ascertaining the percentages of each species or variety, and also by using, in conjunction, the ranges of several gentes, smaller divisions may be possible. Genetic zones determined in this manner should be capable of a very wide application.

Work of this kind has a bearing on many other problems

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besides those of a purely stratigraphical nature. We learn not only the lines of evolution followed by certain fossils, but may hope to throw light on some of the numerous questions dealing with the influence of physical environment, on the relative value of faunal and lithological lines as time indices, and directions of migration. The field of investigation is, indeed, a very wide one, and one may hope that it will lead to many lines of research which are comparatively new to Scottish geologists.

Continual references to the papers on which the foregoing remarks are based have been purposely omitted. For these details the reader is referred to a good bibliography appended to Mr. Douglas's recent paper on "The Carboniferous Limestone of County Clare," *Quart. Journ. Geol. Soc.*, vol. lxv. (1909), p. 582. To that list may be added a note by M. Delépine (appearing in the "Comptes Rendus des Séances de l'Académie des Sciences (Géologie), Paris, 1910") dealing with the recognition of Dr. Vaughan's zones in the Carboniferous Limestone of Belgium. As this articles goes to press, Mr. Stanley Smith has published a paper on "The Faunal Succession of the Upper Bernician" (Trans. Nat. Hist. Soc. of Northumberland, Durham, and Newcastle-upon-Tyne, new series, vol. iii., part 3, pp. 591-645), which is of particular interest to Scottish geologists, as the strata concerned in many ways approximate to our own.

Finally, I would call special attention to the monograph by Professor T. M'Kenny Hughes on "Ingleborough," published in the *Proceedings* of the Yorkshire Geological Society in the years 1901, 1902, 1905, 1906, 1907, and 1908. The two concluding articles of this series (*loc. cit.* vol. xvi., part ii. (1907), pp. 177-196, and vol. xvi., part iii., pp. 253-320) deal especially with the Carboniferous rocks, and are the embodiment of a lifetime's experience of the district. They are full of invaluable facts and of advice to those who wish to engage in Carboniferous work, and a reference to them should on no account be omitted.

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PROCEEDINGS OF THE GEOLOGICAL SOCIETY OF GLASGOW.

SESSION 1909-1910.

(Fifty-second Session.)

REPORT OF THE COUNCIL FOR 1908-1909.

(Submitted 11th November, 1909.)

The Council beg to submit to the members a report on the work and progress of the Society during the last twelve months. It is much to be regretted that there has been a slight decrease in *Membership* from last year, and it is earnestly hoped that the members will endeavour to induce their friends and those interested in the science to join the ranks of the Society.

The Financial State of the Society will be reported upon by your Hon. Treasurer, and it will be found that he is able to report, upon the whole, favourably as to the present position of the Society in that respect.

The Meetings of the fifty-first Session, nine in number, were taken part in by fully the average number of members—about forty.

The Papers and Specimens submitted at the various meetings were of great importance and interest. Among these may be mentioned Mr. Tyrrell's papers on "A New Occurrence of Picrite in the Ballantrae District and its Associated Rocks," "The Geology and Petrology of the Igneous Intrusions of the Kilsyth and Croy District," "The Classification of the Post-Carboniferous Intrusive Igneous Rocks of the West of Scotland," and a paper jointly with Mr. N. Martin on the "Geology and Petrology of the Auchineden District, Kilpatrick Hills"; Mr. Boyle's paper on the "Economic and Petrographical Geology of the New Red Sandstones of the South of Scotland, with their Associated Breccias"; Professor Gregory on "Sideroplesite in the Glenboig Fireclay"; Mr. P. Macnair on "Eyed Coal from Cambuslang." This list shows that the Session's work has been largely devoted to the petrology of the local igneous rocks, the study of which has been considerably advanced by the members of the Society within the last few years.

A large number of interesting exhibits were also brought before the Society. Special mention ought to be made of the fine series of photographs, illustrative of the principal geological phenomena seen during the season's excursions, taken by Mr. J. W. Reoch.

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The Excursions during the summer, nineteen in number, were in most cases largely attended, and were as follows:—

1. Kelvingrove Museum. Mr. Macnair.
2. Hunterian Museum. Prof. Gregory.
3. Brodick, Arran. Mr. Reoch.
4. Corrieburn. Mr. Anderson.
5. Ardrossan and Saltcoats. Mr. Smith.
6. Tyndrum. Mr. Macnair.
7. Duncomb, Kilpatrick Hills. Mr. Watt. (Joint with *Nat. Hist. Soc.*)
8. Burn Crooks and the Whangie. Mr. Tyrrell.
9. Shettleston. Mr. Begg.
10. Murroch and Auchenreoch Glens. Mr. Chalmers.
11. Seedhills Clayfield, Paisley. Mr. Smith.
12. Finnich and Dhu Alt Glens. Mr. Sinclair.
13. Garngad. Mr. Neilson.
14. Mauchline, Ballochmyle, and Ayr Water. Mr. Ferguson.
15. Thornton Hall and Hairmyres. Mr. Neilson.
16. Fiddler Gill, Crossford, and Tillietudlem. Prof. Burns.
17. Innellan and Dunoon. Mr. Macnair.
18. Carron Bridge, Dumfriesshire. Mr. Smith.
19. Gryfe Valley, Bridge of Weir. Prof. Gregory.

Mr. SINCLAIR will report to you upon the Library. He has spent much time during the past Session getting the books into order, and as an arrangement has been made with the Philosophical Society for the erection of an additional bookcase in the lecture-room, Mr. Sinclair hopes to have the Library in complete working order during the coming Session.

Part 2 of vol. xiii. of the *Transactions* was issued to the members early in the Session.

Perhaps the most important event of last year was the celebrating of the Jubilee of the Society, which took the form of a special meeting and conversazione, held on the 28th January, 1909, in the University. In connection with the Jubilee a special volume dealing with the history of the Society was also issued.

Another important feature of last season was the delivering of two papers by Mr. David P. M'Donald, Baxter Demonstrator in Geology in Glasgow University. One of these dealt with "Isomorphism: its Relation to the Chemical Composition and Physical Characters of Crystals"; the other with the "Optical Characters of Minerals"; the latter, taking the form of a demonstration, was given in the geological laboratory of the University.

During the year the Society lost three members by death—Mr. Matthew Blair, who died on the 6th November, 1908, and whose death has been a great loss to the Society, as, for a period of over eighteen years, he took an active interest in all its work. The other members removed by death during the last year were Mr. William Clark, who died in September, 1908; and Mr. Andrew S. M'Clelland, C.A.,

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who died on the 9th March, 1909. Mr. M'Clelland joined the Society in 1866; he had reached an old age, and was for many years well known as a leading accountant in Glasgow.

SOCIETY'S ROOMS, 207 BATH STREET, 15TH OCTOBER, 1909.

The first meeting of the fifty-second Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., *President*, in the chair.

The Minutes of the previous meeting were read and adopted.

Mr. A. C. KERR exhibited a vertebra of a whale from Causeway-head, Stirling, and described the beds in which it was found.

Mr. D. KERR exhibited plant remains of Tertiary age from Spitzbergen.

Mr. A. L. DU TOIT, B.Sc., F.G.S., of the Geological Survey of Cape Colony, then delivered an address upon "The Geology of Cape Colony," in which he said that below the oldest rocks, the geological age of which is definitely known (Devonian), are several systems and series of rocks separated from one another by unconformities. These ancient formations comprise rocks of both volcanic and sedimentary origin, which sometimes have been greatly metamorphosed by granite intrusions. The coastal portion of the Colony is formed principally by the rocks of the Cape system (Devonian and Carboniferous). In the south these strata are greatly folded, and the quartzites of the Table Mountain series give rise to the great coastal ranges, with predominant east and west trend. The folds die out northwards, and the centre and north-east of the Colony are built up of nearly horizontal Karroo strata, a lacustrine formation of immense thickness which has yielded the remarkable Karroo reptilian fossils. The beds extend in age from Carboniferous to Jurassic, and on the Basutoland border they are overlain by vast thicknesses of basaltic lavas comparable with the Carboniferous around Glasgow. The base of the Karroo system throughout South Africa is formed by the celebrated Dwyka conglomerate of glacial origin. The rock is a hardened till or boulder clay, having an extraordinarily close resemblance to the Pleistocene glacial material covering Scotland. It contains striated boulders, and north of latitude 34 degrees S. rests unconformably upon a glaciated surface of older formations. These boulder deposits must have been formed during late Carboniferous times by a vast ice sheet which radiated outwards from a point situated probably in Northern Transvaal. Glacial conditions prevailed simultaneously in India, Australia, and South America; in the northern hemisphere the Coal Measures were in process of formation. Of immense interest is the fact that in Cape Colony there are two other similar formations of glacial origin, one in Devonian and the other in pre-Devonian times. They constitute a strong argument in favour of the doctrine of uniformity, and prove that the average temperature of the crust of the earth, even in remote geological periods, was not

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appreciably warmer than in Tertiary times. The Karroo strata are riddled by sheets and dykes of intrusive dolerite. To the hardness of the igneous rock, and its ability to resist the action of the weather, is due the peculiar scenery of the Karroo, the remarkable isolated dolerite-capped kopjes, with intervening shale and sandstone flats, and the old jagged ridges formed by dolerite sills. The intermittent uplift of the continent of Africa in late geological times has deprived Cape Colony of any navigable rivers.

(Signed) J. W. GREGORY.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH NOVEMBER, 1909.

The second meeting of the fifty-second Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., *President*, in the chair.

The Minutes of last meeting were read and adopted.

The Report by the Council, the Treasurer's Report, and the Librarian's Report for Session 1908-1909 were then read, and, on the motion of Mr. MACINTYRE, seconded by Mr DUNLOP, were unanimously adopted, the President remarking on their gratifying nature.

The following office-bearers were elected:—

Vice-President—Mr. John Renwick, proposed by Mr. Joseph Sommerville and Mr. William Sinclair.

Members of Council—Mr. William M'Creath, C.E., M.I.M.E., proposed by Mr. J. W. Reoch and Mr. P. Macnair; Mr. Alexander M'Lean, proposed by Mr. J. W. Reoch and Mr. William Sinclair; Mr. D. P. M'Donald, M.A., B.Sc., proposed by Mr. P. Macnair and Mr. G. W. Tyrrell; Mr. M. Monie, M.A., proposed by Mr. J. Sommerville and Mr. R. W. Dron.

The following members were elected:—

As an Honorary Associate Member—Mr. David Pearson, proposed by Mr. Joseph Sommerville and Mr. John Renwick.

As an Ordinary Member—Captain H. G. Lyons, F.R.S., LL.D., &c., Lecturer in Geography, the University, Glasgow, proposed by Prof. J. W. Gregory and Mr. G. W. Tyrrell.

Mr. JOSEPH SOMMERVILLE made reference to the resignation by Mr. F. Mort, M.A., B.Sc., F.G.S., F.R.S.G.S., of the office of Joint Hon. Secretary, and, after expressing the highest appreciation of the large amount of useful work done by him for the Society during the last four years, proposed a hearty vote of thanks for the very valuable services rendered by him, which was carried by acclamation. The Council had appointed Mr. James W. Reoch to fill the vacant office.

Mr. JOSEPH SOMMERVILLE also proposed a vote of thanks to the other retiring office-bearers for their services.

Mr. JOSEPH SOMMERVILLE gave notice that at next meeting he would move that, as agreed by the Finance Committee and the Council, the sum of £13 10s. be taken from the credit balance of £183 10s. in the

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Life Subscription account to reduce the balance of £14 8s. 6d., due the treasurer in the Jubilee Celebration account, leaving only a small sum now to be cleared off.

Thereafter the meeting was devoted to the exhibition of specimens.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., *joint Hon. Secretary*, exhibited on behalf of Mr. JOHN SMITH a specimen from an aplite vein containing Sölvsbergite from Howford Bridge, Ayr Water.

Mr. G. W. TYRRELL, A.R.C.Sc., showed an interesting series of specimens, including fossils from the Chalk of Hertfordshire, some fine examples of flint pseudomorphs, *Lepidodendron sternbergi*, and fluorite on calcite and barytes from Lugton, Ayrshire; also making remarks on their occurrence and peculiarities.

Mr. JAMES W. REOCH, *joint Hon. Secretary*, exhibited a collection of fossils from a mass of rock of Liassic age occurring in a Tertiary volcanic vent in Arran, these being notable as showing the former existence of Mesozoic rocks in the Clyde area not now found *in situ*, and pointing to the vast denudation which must have taken place since their deposition.

Mr. DAVID NIMMO exhibited an undescribed crustacean from the Silurian rocks of the Logan Water, Lesmahagow. Its affinities have not yet been exactly determined, but it is probably allied to the Phyllopoda.

Mr. GAVIN M'CALLUM showed the horn of a red deer in a sub-fossil condition, coated with carbonate of lime, and a bronze spear head which had been obtained from excavations at Rothesay Dock, Clydebank, at a depth of about 14 feet below high-water mark, and briefly described the deposits in which they were found.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., *joint Hon. Secretary*, then exhibited some fine specimens selected from the Slimon collection of fossils recently gifted to the Museum at Kelvingrove, including the rare *Lingula scotica*, *Streptorhynchus crenistria* var. *radialis*, *Thelodus scoticus*, *Birkenia elegans*, *Eurypterus obesus*, &c., making interesting references as to their occurrence and characters.

(Signed) J. W. GREGORY.

SOCIETY'S ROOMS, 207 BATH STREET, 6TH DECEMBER, 1909.

The third meeting of the fifty-second Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., F.G.S., *President*, in the chair.

The Minutes of last meeting were read and adopted.

Mr. JOSEPH SOMMERVILLE moved, in accordance with notice given by him at the meeting of the 11th November last, "That as agreed by the Finance Committee and Council, the sum of £13 10s. be taken from the credit balance of £183 10s. in the Life Subscription account to reduce the balance of £14 8s. 6d. due to the Treasurer in the Jubilee

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Celebration account, leaving only a small sum now to be cleared off." Mr. TYRRELL seconded, and the motion was carried unanimously.

The following members were elected:—

As Ordinary Members—Mr. Arthur E. Shute, 12 Clydeview, Partick, proposed by Mr. E. W. Gemmell and Mr. James Stewart; Mr. Gavin W. M'Callum, Kelvingrove Museum, Glasgow, proposed by Mr. Peter Macnair and Mr. James W. Reoch.

As Associate Members—Mr. Herbert Priestley, 8 Glen View, Paisley, proposed by Mr. Peter Macnair and Mr. James W. Reoch; Mr. William Miller, 23 Mar Street, Dennistoun, proposed by Mr. Peter Macnair and Mr. James W. Reoch; Mr. George Watson, 9 Lumsden Street, Overnewton, proposed by Mr. Peter Macnair and Mr. James W. Reoch; Mr. James Stewart, 49 Benview Street, Glasgow, proposed by Mr. Peter Macnair and Mr. James W. Reoch; Mr. John Caisley, 49 Benview Street, Glasgow, proposed by Mr. Peter Macnair and Mr. James W. Reoch.

Mr. JAMES NEILSON drew the attention of the meeting to the presentation to the Society by Mr. John Smith of his recently published work, "Upland Fauna of the Old Red Sandstone, Carrick." He remarked on the novelty and great interest of this discovery by Mr. Smith of fossils in the patches of sedimentary strata enclosed in the lava flows of the Old Red Sandstone; and moved that the thanks of the Society be given to Mr. Smith for this his latest of a long series of contributions, which was heartily agreed to.

Mr. R. G. CARRUTHERS, of H.M. Geological Survey, read a paper on "Zonal Work in Lower Carboniferous Rocks, with some remarks on the Collection of Fossils." [See *Transactions*, vol. xiv., p. 65.]

(Signed) J. W. GREGORY.

SOCIETY'S ROOMS, 207 BATH STREET, 13TH JANUARY, 1910.

The fourth meeting of the fifty-second Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., F.G.S., *President*, in the chair.

The Minutes of last meeting were read and adopted.

The following members were elected:—

As Ordinary Members—Miss Margaret F. Macphee, Broompark, Helensburgh, proposed by Professor J. W. Gregory and Miss A. T. Neilson; Mr. Murray Macgregor, H.M. Geological Survey, 156 Stanmore Road, Glasgow, proposed by Mr. E. M. Anderson and Mr. G. W. Tyrrell.

As an Associate Member—Mr. Frank A. B. Preston, 16 Waverley Park, Shawlands, proposed by Mr P. Macnair and Mr. J. W. Reoch.

Professor GREGORY delivered his presidential address on "Work for Glasgow Geologists—the Problems of the South-Western Highlands." [See *Transactions*, vol. xiv., p. 1.]

(Signed) JOHN RENWICK.

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SOCIETY'S ROOMS, 207 BATH STREET, 10TH FEBRUARY, 1910.

The fifth meeting of the fifty-second Session of the Geological Society of Glasgow was held here this evening—Mr. JOHN RENWICK, *Vice-President*, in the chair.

The Minutes of last meeting were read and adopted.

The following were elected as Ordinary Members:—Mr. Alexander Elliott, 87 Holmlee Road, Langside, proposed by Mr. Robert D. Stewart and Mr. William Lyle; Mr. John Munro, 95 Waterloo Street, proposed by Mr. William Sinclair and Mr. J. W. Reoch.

Mr. JOHN SMITH read a paper on "The Carboniferous Rocks of the Solway, Scotland." [See *Transactions*, vol. xiv., p. 30.]

(Signed) J. W. GREGORY.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH MARCH, 1910.

The sixth meeting of the fifty-second Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., F.G.S., *President*, in the chair.

The Minutes of last meeting were read and adopted.

Mr. WILLIAM SINCLAIR, *Librarian*, moved that a vote of £15 be granted for Library purposes, which was seconded by Mr. JAMES NEILSON, and carried.

Mr. ROBERT DUNLOP read a paper on "The Fossil Amphibia in the Kilmarnock Museum previous to the Fire of 1909." [See *Transactions*, vol. xiv., p. 60.]

Mr. JAMES W. REOCH, *joint Hon. Secretary*, exhibited a large series of lantern slides of photographs taken at localities visited by the Society during the year 1909.

Mr. ROBERT DUNLOP exhibited an interesting set of lantern slides in illustration of Mr. John Smith's recent paper on the "Carboniferous Rocks of the Solway," chiefly relating to the section at Arbigland, and including many fine examples of corals.

(Signed) JOSEPH SOMMERVILLE.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH APRIL, 1910.

The seventh meeting of the fifty-second Session of the Geological Society of Glasgow was held here this evening—Mr. JOSEPH SOMMERVILLE, *Vice-President*, in the chair.

The Minutes of last meeting were read and adopted.

Mr. GEORGE C. WATSON exhibited specimens of *Myacites sulcata* from Bishopbriggs Quarry, also *Lepidodendron veltheimianum*, and fragments of scorpion skins from Giffnock Quarry, and briefly described the localities from which he had obtained them.

Mr. D. P. M'DONALD, M.A., B.Sc., Baxter Demonstrator in Geology in the University of Glasgow, read a paper on "The Genesis of Iron

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Ores." Iron-containing minerals are widely distributed throughout the rocks of the earth's crust, and the processes of concentration of these are of great interest. The chief commercial ores are the oxides and the carbonates. Ore masses of magnetite may be formed either by the differentiation of the iron oxide from an igneous magma or by the subsequent metamorphism of another ore. The enormous deposits in Scandinavia furnish splendid examples of this. Hæmatite frequently occurs in large lenticles enclosed in limestone. The ironstone has replaced the calcium carbonate. Iron-bearing solutions percolating through a limestone may result in the deposition of either hæmatite or chalybite. Subsequent oxidisation may convert the carbonate into the oxide. The presence of fossils converted into hæmatite is strong evidence for this change. Contemporaneous replacement of limestone seems to have sometimes occurred. Limonite, the hydrated iron oxide, is deposited directly from ferruginous solutions either owing to direct oxidation or to the action of plant organisms. Blackband ironstone is a bedded ore formed by direct precipitation. The deposition as a carbonate and not as an oxide must be explained. The water in the carboniferous lagoons may have been saturated with carbon dioxide, and thus the oxidation of the iron may have been prevented. In the Clyde basin the iron was probably leached out of the surrounding lavas.

(Signed) J. W. GREGORY.

SOCIETY'S ROOMS, 207 BATH STREET, 12TH MAY, 1910.

The eighth meeting of the fifty-second Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., F.G.S., *President,* in the chair.

The Minutes of last meeting were read and adopted.

The following were elected as Ordinary Members:—Mr. George A. Brown, 35 Sunnyside Road, Coatbridge, proposed by Mr. James Neilson and Mr. Robert Dunlop; Mr. James Wright, junior, 36 Douglas Street, Kirkcaldy, proposed by Mr. James Neilson and Mr. Robert Dunlop.

Mr. J. W. REOCH exhibited, on behalf of Mr. JOHN SMITH, siliceous rocks, with emerald and black chromite, from Crock Hill, West Kilbride, and from Diamond Hill, West Kilbride, and read notes descriptive. The specimens were taken from stones in the volcanic ash of the above-mentioned hills. These siliceous stones evidently came up the volcanic vents; and it is thought they have likely been derived from a rock originally a limestone and which has got replaced by silica.

Mr. ROBERT DUNLOP exhibited an interesting collection of fossil shells from Greenfoot Quarry, near Glenboig, and fully illustrated and described the section where they occurred. These included some twenty-four species, eleven of which had been recorded by the Geological Survey. A large number of them were remarkable for their

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close affinity to American fossils, notable among these being *Prothyris elegans*.

Mr. ROBERT DUNLOP then read a paper entitled "Remarks on Some Crinoids, with Specimens and Lantern Slides." At the outset he alluded to the rarity of complete heads of crinoids from the west of Scotland, as shown by various collections. Of recent years, however, he had been successful in finding many very fine specimens. In the Carboniferous System of Scotland, as in the Devonian limestone of England, where you get abundance of corals, there you will not find many encrinites, and *vice versa*, but at Invertiel, Roscobie, and Bankend, crinoids are generally accompanied by small specimens of *Zaphrentis*. The larger crinoid heads are generally crushed, but the smaller are sometimes very perfect. The stems again are found to form great masses of encrinal limestone, but it is in the limestone shales that the finest specimens of heads have been found. The knowledge of these interesting fossils has been hindered by the fact of no one having made this group a speciality in Scotland. The crinoids are nearly related to the star-fishes and sea-urchins, but while the two latter have flourished to the present time, the former have almost disappeared. The author alluded to the work of Dr. Bather, of the British Museum, on the Crinoidea, and to that of Wachsmuth and Springer on the American species.

He then showed a large number of lantern slides from figures by various authors, giving a historical outline of our knowledge of Crinoidea, and describing their structure. Then followed a very fine series of illustrations of his Scottish specimens, along with views of the localities where they had been found.

Mr. D. P. M'DONALD, M.A., B.Sc., Baxter Demonstrator in Geology in the University of Glasgow, gave a demonstration on "The Occurrence of Igneous Rocks in the Field, with Lantern Illustrations." Commencing with illustrations of recent lava flows at Vesuvius and Mont Pelée, he next illustrated the extinct cinder cones of Auvergne, the volcanic necks of Stockie Muir, and various necks of agglomerate; then showed numerous examples of basalt flows, with columnar structure, and jointing; intrusions in the forms of sills, dykes, and veins, with their effects on the rocks invaded by them; leading finally to the deeper-seated and plutonic rocks as exemplified in the gabbro of Skye, the granite of the Mourne Mountains of Ireland, and the microgranite of Ailsa Craig. Descriptive and explanatory notes were given throughout.

The meeting then adjourned until next Session.

EXCURSIONS FOR SEASON 1910.

To Kelvingrove Museum, on Saturday, 12th March—Mr. Peter Macnair, F.R.S.E., F.G.S., conductor. The party met in the Geological Gallery at 3 p.m., and examined some of the recent additions to the geological collections, including the Slimon collection of Upper Silurian fossils.

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To Girvan, on Monday, 28th March (Spring Holiday)—Mr. R. Dunlop, conductor. Here a practically continuous section along the shore south of Girvan shows the Craigskelly Conglomerate (Llandovery), underlain by Barren Flagstones, Whitehouse Group, and Ardwell Group (Caradoc). Highly graptolitic bands occur in the two latter groups, especially opposite Shalloch Mill, and the third milestone from Girvan. At Kennedy's Pass the Ardwell Beds are underlain by the Benan Conglomerate (Llandeilo). The latter overlies conformably a great series of lavas, tuffs, radiolarian cherts and black shales of Arenig age. At Lendalfoot gabbro, diallage rock, and serpentine, belonging to the plutonic phase of the Arenig vulcanicity, are well seen.

To Glenboig, on Saturday, 9th April—Professor J. W. Gregory, D.Sc., F.R.S., conductor. The object of the excursion was to examine the rocks in association with the Glenboig Fireclay, which belongs to the Millstone Grit Series of the Carboniferous System. The Fireclay was seen in the surface outcrops and associated with a series of Millstone Grit Sandstones and an intrusive basic sill. A marine limestone and a shale with marine mollusca, determined by Dr. Wheelton Hind as of American affinities, occur in one of the quarries that were visited. The Fireclay was deposited in a lagoon. The works of the Glenboig Union Fireclay Company, Limited, were afterwards visited.

To Dalmuir Burn, on Saturday, 23rd April—Mr. Peter Macnair, F.R.S.E., F.G.S., conductor. Fine sections occur in the Dalmuir Burn showing limestones, sandstones, and shales, belonging to the Lower Limestone Series. The principal object of this excursion was to examine an outcrop of highly fossiliferous shale, which it is believed had not been previously noted in this locality.

To Garelochhead, on Saturday, 14th May—Professor J. W. Gregory, D.Sc., F.R.S., conductor. The object of this excursion was to examine the rocks on the southern edge of the Highland schists. On the Geological Survey map, Sh. xxx., the rocks near Row are marked as slates separated by an indefinite line from the rocks to the north, which are described as "mica schist and undifferentiated schists." These rocks may be divided into three divisions—a series of slates, greywackes and conglomerates, and two series of schists; the characters of the rocks of two of these divisions were shown by sections visited. The party returned from Shandon station.

To Hindog Glen, Dalry, on Saturday, 28th May—Mr. John Smith, conductor. The last lava-flow (in this district) of the great series of volcanics between the Calciferous Series and the Lower Limestone was seen opposite Whitecraig. Above the lava there are beds of agglomerate and tuff. The Hurlet Coal rests on the tuff. The Hurlet and the White Limestone of Beith are in a single bed. A 60-fathom fault has brought down the Blackband Ironstone to a lower level than the Lower Limestone. The Orchard Limestone was seen, showing its extension into this district. Fossils abundant.

To Cadder Wilderness (evening excursion) on Wednesday, 1st June—Mr. James Anderson, conductor. The object of the excursion was

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to visit the Carron Company's pit at Cadder Wilderness, where Blackband Ironstone is presently being worked.

To Arbigland, on Thursday, 2nd June (Victoria Day)—Mr. John Smith, conductor. The objects of interest were the Calciferous strata with "nosing-out" syncline. Thirlstone Sandstone, much bent in parts—strata greatly twisted and broken. Large shore exposure of limestone, shales and sandstones; fossils abundant, especially corals of the genera *Lithostrotion* and *Syringopora*.

To the Auld Wives' Lifts, Craigmaddie Muir, on Saturday, 11th June—Mr. Wm. Sinclair, conductor. The "Auld Wives' Lifts" are three blocks of grit, one lying on the top of the other two, near the top of the hill at Craigmaddie Muir. The hill is largely made up of siliceous sandstones and loose pebbly conglomerates of Lower Carboniferous age. The igneous intrusions at Mugdock Reservoir were examined *en route*.

To Lanark and the Falls of Clyde, (joint excursion with the Geographical Section of the Royal Philosophical Society of Glasgow), on Saturday, 18th June—Mr. G. W. Tyrrell, A.R.C.Sc., F.G.S., conductor. The Mouse Glen, probably an example of deep post-glacial erosion, was visited. From this point the general character of the country as a young dissected plateau is well seen. The gorge of the Clyde in this district, cut in Old Red Sandstone, is probably post-glacial, and shows fine examples of river erosion and waterfall action. Towards Ravenstruther and Carstairs, Kames were visited, marking the site of the boundary of the old ice-sheet which descended northward from the Southern Uplands. The site of a glacial lake accumulated against this ice-front was also seen.

To Duntocher and Faifley (evening excursion), on Wednesday, 22nd June—Mr. G. W. Tyrrell, A.R.C.Sc., F.G.S., conductor. Roman wall, bridge and camp at Duntocher were visited. The Hurlet Limestone and Coal were seen in quarries in the district. Thence the cup and ring markings at Auchnacraig were examined. On the walk over to Auchnacraig, the white pebbly sandstones of Douglas Muir, underlying the Hurlet Limestone, were also seen.

To Paisley, on Saturday, 25th June—Mr. D. P. M'Donald, M.A., B.Sc., conductor. The Hollybush Limestone at Hollybush farm was visited. In the Glen the volcanics of the Calciferous Sandstone—thick tuffs underlying lavas—were seen. A fossiliferous limestone was also examined in the quarry at Nethercraigs.

To Tory Glen, Chapelhall, on Saturday, 20th August (joint excursion with the Natural History Society of Glasgow)—Mr. James Neilson, conductor. A great fault in this glen has put the Main Coal on one side of it, and the Lower Drumgray and Shotts Gas Coal on the other, all of which are to be seen at the surface. The Shotts Gas Coal is here as a gas coal, shale and free coal. The shale contains fish remains and other fossils. Footprints have been recorded from a quarry close at hand. There are also remains of old coal and ironstone workings, and a fine waterfall. Titanite occurs in the old slags.

To Devol Glen, Port-Glasgow, on Saturday, 10th September—Mr. David Chalmers, conductor. The Ballagan Beds and interbedded

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traps of Lower Carboniferous age were seen. The effects of stream erosion are well displayed.

To Patna, on Monday, 26th September (Autumn Holiday)—Mr. G. W. Tyrrell, A.R.C.Sc., F.G.S., conductor. The sedimentary rocks of the district belong to the Carboniferous Limestone Series and the Calciferous Sandstone, both of which were seen. These are pierced by numerous volcanic rocks, which contain a variety of material. In Patna Hill, blocks of coal, shale, lava, and crystals of biotite and hornblende are found. In the Carclout vent is a remarkable intrusion of porphyritic essexite like the famous Crawfordjohn rock. The Carskeoch vent is made up of an intrusion of monchiquite, bearing huge sporadic crystals of hornblende and biotite. This is pierced in its turn by a boss of essexite.

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ABSTRACT OF THE TREASURER'S ACCOUNTS FOR THE YEAR ENDED 30TH SEPTEMBER, 1909.

CASH ACCOUNT.

RECEIPTS.

To Cash in Bank on Deposit,	£105 0 0	
,, Cash in Treasurer's hands,	1 18 4	
		£106 18 4
,, Subscriptions for current year (including 16 new Ordinary Members)—163 at 10/,		81 10 0
,, Do. 2 at 7/6,		0 15 0
,, Do. Arrears—7 at 10/,		3 10 0
,, Do. Do. 1 at 7/6,		0 7 6
,, Life Membership Subscription,		5 5 0
,, Associate Members' Subscriptions—8 at 2/6,		1 0 0
,, Handbooks and Catalogues sold,		3 6 0
,, Interest on Funds,		8 18 9
,, Balance due Treasurer,		4 3 8
		£215 14 3

EXPENDITURE.

By Transactions—		
Printing and Publishing Vol. XIII., Part 2, and for Reprints of Papers,	£63 15 1	
Postages, Typing, etc.,	4 4 5	
		£67 19 6
,, Library—New Books, Maps, and Magazines,		2 2 9
,, Subscription to Marine Biological Association, 1909,		1 1 0
,, ,, to Palæontographical Society, 1909,		1 1 0
,, Rent, Insurance, and Attendance,		13 10 0
,, Printing and Postage of Circulars, Excursion Booklets, and Advertising,		21 6 6
,, Lantern Expenses,		2 9 3
,, Collector's Commission,		0 12 9
,, Disbursements by Hon. Secretaries, Postages, Stationery, and Petty Expenses,		5 11 6
,, Jubilee A/c.—Amount voted by Society to account of Expenses,		100 0 0
		£215 14 3

JUBILEE CELEBRATION ACCOUNT.

To Subscriptions,		£79 10 6
,, Sum voted by Society,		100 0 0
,, Jubilee Volumes (History of the Society) sold,		5 0 0
,, Balance due Treasurer,		14 8 6
		£198 19 0
By Printing and Publishing Jubilee Volume, "History of the Geological Society of Glasgow, 1858-1908,"		£135 15 7
,, Expense of Conversazione in Bute Hall,		60 19 11
,, Disbursements by the Hon. Secretaries, Printing, Postages, and Advertising,		2 3 6
		£198 19 0

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STOCK ACCOUNT.

To Life Subscription Account, ...			£183	10	0	
,, Balance due Treasurer—						
As per Receipts and Expenditure Account,	£4	3 8				
Do. Jubilee Celebration Account, ..	14	8 6				
			18	12	2	
,, Mr. Charles R. Cowie's Donation and accrued Interest, ..			103	1	9	
,, Capital Account,*			567	17	10	
			£873	1	9	

* NOTE.—Subject to cost of publishing *Transactions*.

By Campbeltown Corporation Loans, ...			£270	0	0	
,, Property—						
Books in the Library, ...	£440	0 0				
Furniture, Bookcases, and Microscope, ..	60	0 0				
			500	0	0	
,, Mr. Charles R. Cowie's Donation—Cash in Bank on Deposit Receipt, ...			103	1	9	
			£873	1	9	

LIFE SUBSCRIPTION ACCOUNT.

Sept. 30, 1909.—To Amount voted to account of Jubilee Expenses,			£100	0	0	
,, Balance to Credit, ...			183	10	0	
			£283	10	0	

October 1, 1908.—By Balance, ...			£278	5	0	
Sept. 30, 1909.—By Subscription during Year, ...			5	5	0	
			£283	10	0	

Mr. CHARLES R. COWIE'S DONATION.

Sept. 30, 1909.—To Balance to Credit, ...			£103	1	9	
			£103	1	9	

Oct. 1, 1908.—By Cash in Bank, ...			£101	14	9	
Sept. 30, 1909.—Interest, ...			1	7	0	
			£103	1	9	

GLASGOW, *4th November*, 1909.—Examined, compared with relative Vouchers and Securities, and found correct, the Accounts showing a balance due Treasurer of Eighteen Pounds Twelve Shillings and Two Pence.

D. PEARSON,
ARCH. A. YOUNG, } *Auditors.*

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. V.—The Glasgow Earthquake of 14th December, 1910. Presidential Address.

By J. W. Gregory, D.Sc., F.R.S., University, Glasgow.

[Delivered on 12th January, 1911.]

The Midland Valley of Scotland has been formed and its chief geographical features determined by an intricate network of faults. Faults separate the Midland Valley from the Highlands to the north and the Southern Uplands to the south; upraised fault-blocks form some of the most conspicuous features in the scenery, such as the Campsie Fells and the Fintry Hills; and coalfields preserved in basins due to down-faults have been the main factor in the economic development of the country. These faults doubtless extend to a great depth beneath the surface; for not only are the Carboniferous rocks immediately beneath Glasgow intensely faulted, but it may be inferred from the older rocks at their nearest outcrops that the Glasgow district had been much faulted even earlier than Carboniferous and Devonian times. The geological principle is now well established that later movements in the earth's crust tend to follow the lines of older movements. Hence we might reasonably expect that faulting is still in progress in the Glasgow district; and several geographical features indicate that some fault movements are of comparatively recent date. It is not surprising that small earthquakes are frequent along

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the Highland Boundary Fault, which separates the Midland Valley from the Southern Highlands, and the interesting catalogue of earthquakes ranging from 1570 to 1889, published by Dr. David Murray in the *Glasgow Herald* of 20th December, 1910, shows that noticeable earthquakes in this district are not uncommon. The earthquake of 14th December appears, however, to have been the most severe in living memory.

Earthquakes in big cities cannot be safely ignored. The study of an earthquake, which in a Highland district may be only of academic interest, is of practical importance in a city underlain by a plexus of water pipes, sewers, gas pipes, and electric mains. For an earthquake shock may start leaks causing costly waste and serious injury to public health.

The many correspondents who have so kindly sent me a statement of their observations have therefore done useful service by contributing a collection of personally recorded facts which serve to show the origin and path of the recent earthquake. Their letters will be preserved in the University library, so as to be available for detailed comparison with future earthquakes.

The recent earthquake was one of a world-wide series, which began on the morning of the 14th December, 1910, with a powerful earthquake along the eastern coast of Africa at 11.40 a.m. Greenwich mean time. It was followed by such severe shocks elsewhere that, according to the *Times* of 19th December, Dr. J. J. Shaw, of West Bromwich, described the week including the 14th December as "the most disturbed week he ever knew." Dr. J. Milne has recorded in *Nature* a succession of large earthquakes, including those on 14th December in East Africa, on 16th December in New Guinea, on 17th December in the West Indies, on the 18th one at 4 a.m. in Java and one at 5.49 a.m. in the West Indies. Each of these shook half the world. Others followed in the new year, culminating on 4th January in the disastrous earthquake around Tashkend, in Central Asia.

The Glasgow earthquake probably had no direct connection with the others, but they may all have had a common cause. It was claimed by Perrey that earthquakes are especially numerous near the times of full and new moon when the tidal strain on the earth's crust is at its greatest. The evidence

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quoted in support of this view has been shown by Professor Knott to be unconvincing; but it has been reaffirmed in 1906 from the Greek seismic observatory,* and, as the first group of the recent series happened near full moon, and the second group near new moon, they add to the list of such approximate coincidences.

The local series began on the evening of 14th December with a very faint shock at Ayr between 6.45 and 7 o'clock. Evidence of this earthquake has been kindly reported to me by Dr. Morton [84].† At 8.54 p.m. the Glasgow district was shaken by a sharp shock, which was followed by some fainter earthquakes, of which two were recorded on the Paisley seismograph at 9.26 and 9.29 p.m. They were barely perceptible in Glasgow, though felt by a few people. Secondary shocks were noticeable at Rosneath and Kilcreggan; at Cathcart at 9.10 p.m.; at Swinton, Easterhouse, near Coatbridge, at 9.46 p.m.

The main shock occurred at 8.54, and it was most powerful in the north-western suburbs of Glasgow, and was felt by various observers to distances of about 10 miles from its centre.

It is unfortunate that there was no seismograph in the district that would give information about earthquakes of local origin. The Coats Observatory at Paisley has a Milne horizontal-pendulum seismograph, the instrument which has done so much to advance modern seismology. It was designed to record and interpret the tremors transmitted from far distant earthquakes, but it gives little information about shocks of local origin. The Paisley Observatory also has a Ewing seismometer, which interprets the movements of local earthquakes, but this instrument was not in action at the time.

The recent earthquake can be best tracked to its centre of origin by use of the Rossi-Forel scale of earthquake intensity, which is the scale most useful for the study of slight and

* "Etude des Séismes survenus en Grèce pendant les années, 1900-1903." By D. Eginitis. "Annales de l'Observatoire National d'Athènes," 1906, vol. iv., pp. 135-145. *Fide* an abstract by Mr. Belinfante in Trans. Inst. Min. Eng., vol. xxxii, 1908, p. 582.

† The thick Nos. in brackets refer to the list of letters in Appendix II.

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moderate shocks. Earthquakes are divided by this scale into ten grades—from No. 1, the slightest, to No. 10, the most severe. The classification is based on such simple observations and experiences as are not likely to vary much with the imagination of the observer, and can be collected after the earthquake. The different divisions are not sharply defined and they are of unequal value; and the characters have to be used with discretion, or an earthquake may be unduly promoted owing to the peculiar elasticity of jerry-built houses. Care is especially necessary in a mining district, where buildings may stand above abandoned coal pits, and the collapse of old workings may exaggerate the earthquake effects. Thus in three localities near Glasgow a house was so badly shaken that the inmates left in alarm, a character that would indicate an earthquake of intensity No. 6. Yet in one of these cases people in an adjacent house did not even notice the earthquake. Again, the shock was very feeble at Cathcart, yet the worst cracking of the plaster in ceilings was caused in a house there by the slight secondary shock at 9.10 p.m. Such exceptional cases may be explained by local weakness in the foundations.

For the scientific comparison of earthquakes numerical estimates are most important, but I have not obtained any reliable data as to the velocity or size of the earthquake waves. I have therefore added to the table of the Rossi-Forel scale Professor Holden's estimates of the intensities as determined by the accelerative effect, for these numbers afford some measure of the relative intensities of the different degrees on the scale.

The recent earthquake appears to have attained the rank of about 5½ or between "moderate" and "fairly strong" in the area most affected. It was therefore milder than the earthquake at Colchester in April, 1884, which must have reached the degree of 8·5, and of those at Inverness in September, 1901, and at Pembroke on 18th August, 1892, both of which, according to Dr. Davison, reached grade No. 8. Nevertheless, thanks to the improvements in the sensitiveness of seismographs, our earthquake appears to have beaten the British record in one respect, for, according to Dr. Milne, it was recognised at a greater distance than any other earth-

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quake of British origin. Dr. Milne has kindly informed me that the earthquake was recorded in his observatory at Shide, in the Isle of Wight, and also by seismographs at Guildford. The movement of 9·26 was also felt at Shide, Bidston (Liverpool), and Stonyhurst. The movements were all very slight, and in a letter received this morning he says, "It was a great surprise to me to find that your earthquake had travelled as far as the Isle of Wight. The first British earthquake ever recorded took place in the year 10, when the castle at Edinburgh was shaken. Your last one has beaten all others for distance. Scotland for ever."

THE ROSSI-FOREL SCALE.

Grade of Intensity.	Characteristics.	Description.	Corresponding acceleration according to Prof. E. S. Holden.
			per sec.
1.	Recorded by delicate seismographs	Imperceptible.	20 mm.
2.	Recorded by all seismographs; felt by occasional people at rest	Extremely feeble.	40 ,,
3.	Felt by several people at rest; direction and duration appreciable	Very feeble.	60 ,,
4.	Felt by people in motion; movable objects disturbed; ceilings cracked	Feeble.	80 ,,
5.	Felt by everybody; furniture disturbed; light bells rung	Moderate.	110 ,,
6.	Most sleepers wakened; most bells rung; trees visibly shaken; some people leave their houses	Fairly strong.	150 ,,
7.	Objects overthrown; church bells rung; general panic	Strong.	300 ,,
8.	Chimneys overthrown; walls of buildings cracked	Very strong.	500 ,,
9.	Some buildings destroyed	Violent.	1200 ,,
10.	Complete devastation	Catastrophic.	—

From the epicentre the shock diminished quickly in strength to Nos. 4 and 3, dying away as a barely imperceptible shock of grade No. 2 at Bowling or perhaps Dumbarton [1] in the west and Glenboig in the east. The area over which the earthquake had an intensity of No. 2 and upwards was therefore about 20 miles from west to east and 15 from north to south,

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and, allowing for the irregularity of its margin, it affected about 300 square miles. Some occasional records may be expected outside the area included in the above estimate. Thus the earthquake was appreciably felt in the Rosneath peninsula [2], which is crossed by the Highland Boundary Fault from Rosneath to Kilcreggan; and the account of the shock there, which has been sent me by Miss H. Story, would indicate an earthquake with an intensity above No. 2. Its recognition there was probably due to the imperceptible earth wave breaking against the Highland Boundary Fault, and thus causing a secondary local vibration.

The distribution and varying strength of the earthquake are shown on map (Fig. 1), based on the information received in the correspondence catalogued in Appendix No. 11. and from that published in the Glasgow newspapers.

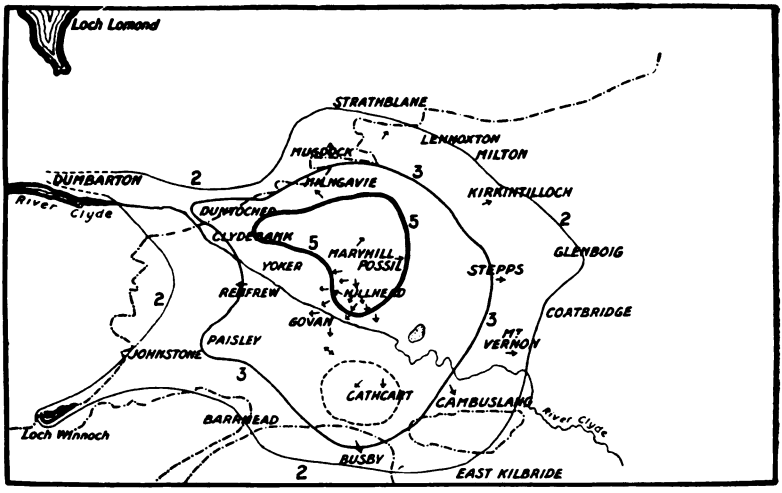

FIG. 1.—Lines of Equal Intensity (Isoseists). Nos. 2-5 are the degrees on the Rossi-Forel Scale. The dotted line around Cathcart shows the area of the earthquake at 9.10 p.m. Scale—1 inch = about 8 miles.

In the north-western suburbs of Glasgow the shock was felt by most people except those who were busily engaged. It woke up a few sleepers; it rung some bells in Hillhead; it occasionally disturbed furniture; it overthrew some dishes and pottery that were in insecure positions; and it widened or made

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a few cracks in plaster. But as there are no reports of several of the characters of intensity No. 6, it seems not to have reached that degree in the Rossi-Forel scale.

The earthquake decreased to the intensity of No. 4 in Milngavie, around Glasgow Bridge, and in Govan; to intensity No. 3 at north Milngavie, to the north of Clydebank, at Renfrew, Partick, west Govan, Pollokshields, Cathcart, Rutherglen, Stepps, and west of Kirkintilloch; to intensity No. 2 at Mugdock, south Lennoxtown, Milton of Campsie, Glenboig, Lenzie, Mount Vernon, Cambuslang, Barrhead, and Lochwinnoch. It was apparently a little less than 2 at Dumbarton and East Kilbride; and it was not felt, as far as the records go, at Killearn, Kilsyth, Airdrie, Coatbridge, or Greenock.

As it travelled outward from its epicentre the effect changed. In the central area the shock emerged very steeply from below the ground. It was felt as a short, sharp vibration, and the sounds heard were compared to a rumbling, an explosion, or the fall of a heavy body on the floor overhead. It lasted for from less than one to about two seconds. A little further from the centre a double shock was felt; the two parts, however, followed one another almost immediately. The first of the two was due to the normal wave of compression caused by the direct forward thrust of the earthquake; the second was the transverse or torsional wave, which always travels more slowly than the other, and therefore soon lags behind. Further from the centre the whole wave became much longer, and the horizontal effect became more marked than the vertical, and the shock lasted for several seconds, the estimates varying from five to ten. In the outer zones down to No. 3 a horizontal thrust was sometimes felt before an uplift. Thus Miss Tina Smith, who was in bed at Stepps, described her bed as having been first pushed eastward, brought backward, and then jerked upward [No. 80 received through Mr. Fleck]; this description would accurately represent the probable nature of the movement at that locality. The increase of the horizontal component was shown by the fact that occasionally clocks stopped in the outer zones affected, as at Lennoxtown and in south-eastern Glasgow.

The gradual outward fading of the shock enables the position of the epicentre to be determined approximately. A more

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definite localisation requires more detailed consideration of the evidence from different localities. The first reports showed that the movement at Hillhead was along a north and south line, and it was recognised as having had the same trend at Mugdock and Lennoxtown. But to determine whether the wave travelled from the north or the south is more difficult.

It is often inferred that an object displaced by an earthquake would be inclined or fall away from the earthquake centre. A person on a chair who feels himself pushed westward usually concludes that the movement came from the east; but it would probably have come from the west, for as the floor is jerked eastward the inertia of the weight on the chair would cause it to incline or fall westward. Hence any heavy body in firm contact with the ground, and with its centre of gravity well raised above its base, would usually incline towards the direction from which the shock came. Light objects, however, which may be jerked upward from the ground, would be thrown away from the epicentre. Further, a body so placed that when shaken it swings to and fro, may fall in either direction. Pictures on a wall parallel to the path of the advancing earthquake wave might be tilted, while those on a wall at right angles to the direction would swing outward from the wall, and might fall back to exactly their original position.

The sounds that accompany an earthquake are also used to track it to its source; but in a large city this evidence seems to me less reliable. It is notoriously difficult to determine the direction of sound, and it may be impossible to distinguish the sound due to the passage of the wave through the earth from that made by the structures shaken. Hence the same earthquake may sound like thunder to a man near an iron shed; like the wind to a man beside a forest; or like a rumble to an observer who hears the actual vibration of the ground. The apparent direction of a sound may be misleading, unless allowance be made for the relative velocities of the earthquake and the sound which it has produced. The velocity of sound in Glasgow at 9 p.m. on the 14th December would have been about 1100 feet per second. An observer at the northern end of a room would hear the windows there rattled before those at the southern end if an earthquake coming from the south

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were travelling at a greater velocity than 1100 feet a second. He would probably conclude that the earthquake was travelling from north to south; but the southern end of the room would have been shaken first, although the shaking of the northern windows first reached his ears. A map showing the homacoustic lines, illustrating the distribution of the different sounds, is given as Fig. 2.

Bearing these considerations in mind, the evidence available indicates that the earthquake was travelling in the directions of the arrows marked on the map (Fig. 1). Thus, for example, at Woodlands Terrace a statue was seen to incline northward, showing that its base was pushed southward [**51**]. One of the University janitors—Scott—saw a stink cupboard on a southern wall in the Mining Department jerked northward. Miss Hannan Watson has collected various items of evidence, including the overthrow of bottles and the oscillation of liquids in them, all pointing to a southward movement in Hillhead. A light ornament was thrown from a mantelpiece on a north and south wall in the residence attached to the Anatomy Department of the University, and fell to the south or south-south-east. Our member, Mr. W. A. Buchanan [**41**], saw a picture on the north-north-east wall of a room in 18 Bute Gardens swing outward from the wall, and he remarks that the shock was "quite alarming," and that "I am perfectly certain it came from the north."

Miss Macbeth tells me [**40**] that in the room in which she was sitting the northern wall was first shaken, and the wave distinctly passed from north to south.

The southward course of the wave in the centre of the city is shown by several records. Thus Mr. W. R. Smellie reports the fall northward of "some short, squat ornaments not more than 2 or 3 inches high, and standing on four legs," at Messrs. Dykes Bros.' shop in Royal Exchange Square. They all fell in the one direction, and such objects would probably fall towards the direction from which the shock came. An observer in Gordon Street is reported in the *Glasgow Herald* of the 15th December to have heard a rumbling, then felt a shock, and heard the noise pass southward across the Central Station. My own experience also pointed clearly to a movement from

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north to south at West End Park. I happened to be standing facing east examining some maps on a long table running north and south, and the sensation was that of a sharp jerk upward of the northern end of the room, and its slower fall as the wave passed on, rattling the kitchen pans on the southern wall of the house. The shock lasted less than two seconds, and was so sharp that I feared it might have overthrown a wardrobe standing against the northern wall of my daughter's room, and so, after looking at the time, I rushed there to see that nothing had fallen. The door in a long north-and-south wall, which I had closed only a few minutes before, had been jerked open. Out of ten pictures on a north-and-south wall six were tilted with a slope downward to the south, indicating again a jerk upward from the north.

That the earthquake arose to the north of Glasgow rather than in central Glasgow is also indicated by the fact that it was less severe around the three main railway stations and along Argyle Street than in the northern suburbs. At the Technical College it was noticed by Mr. Boyle, who said it felt as if something had fallen on the roof. Mr. J. W. Reoch, on the other hand, tells me that, although he was "doing microscopic work there at the time, and should therefore have felt any special vibration under the then existing conditions of absolute quiet, when any unusual disturbance that might occur would hardly have passed unnoticed, yet neither I nor any one in my neighbourhood in the class-room observed anything, either of a shock or of a noise." Miss Hughes, who was in the Chemical Laboratory of the same college, also felt nothing, and was accordingly surprised to see some chloroform in a bottle begin to sway to and fro, while fluids of average specific gravity were much less affected. The intensity at the Technical College was therefore scarcely above No. 2. Moreover, the earthquake was unnoticed in several streets near the Trongate and in Bridgeton. Thus, according to the *Glasgow Herald* of 15th December, it was not felt in Marlborough Street or Stevenson Street, near Bridgeton Cross; it was noticed as a faint tremor by some of the men in the Eastern Police Office, and they attributed it to a passing traction engine. A correspondent, who was at the time in a house in Gallowgate,

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opposite Kent Street, heard a noise like the fall of furniture in the room below; but he found, on inquiry of his neighbours in the adjacent parts of London Street, that none of them had noticed anything unusual. The *Glasgow Herald* of 16th December records the stoppage of a clock in the eastern end of the city at 8.54, which showed that the vibrations had became longer and more horizontal in that district than near the epicentre.

The Rev. John Alexander tells me that some prisoners at Duke Street, who were awake in bed at the time, heard and felt the earthquake. They described the building as having been distinctly shaken. The beds are placed north and south, and the feeling was that of a movement from west to east and of a movement like the swaying eastward of the outer eastern wall. The noise was described by some as a rumble, and by others as resembling a distant explosion. The evidence of people lying in bed is especially useful, as they are sensitive to slight movements, the direction of which can often be reliably determined. The evidence from Duke Street is most consistent with a wave travelling eastwards.

The earthquake seems to have originated a little north of Hillhead and Port Dundas, but to the south of Milngavie and Bishopbriggs; for to the north of Maryhill the evidence points to a movement of the earthquake wave from south to north, and the evidence for this direction is still more definite at Mugdock Castle [12] and Lennoxtown. The earthquake was probably not due to a wide movement along a fault, for the movement was radial from a restricted locality. Thus at Kirkintilloch it was travelling from the south-west; at Colston, south of Bishopbriggs, the evidence indicates a movement from a little south of west; at Stepps from the west; in Duke Street Prison from the west; at Jordanhill from north or east; at Maryhill and Hyndland (T. B. Baillie), and Renfrew, from the east. The centre from which the wave spread was probably not more than 2 miles in length.

The evidence of direction is not always consistent. Thus at Copland Street, Govan, one reliable observer records the movement as from east to west, whereas other records from parts of Govan a little further east represent the movement as from

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north to south. Similarly in Anderston and Overnewton, though the general evidence is of a movement from north to south, there are some clear impressions of a movement from east to west. These differences may be explained by the fact that the movement there was from between north and east, and the apparent direction depended as to whether the house could vibrate more readily to the west or south.

Such differences in the record of directions are not limited to personal observers. As Professor Milne has pointed out, instruments which give identical records when placed side by side give very different records when placed 800 feet apart.* The movements of the actual ground at any place will vary with a series of very complex and variable factors, and it is therefore necessary to trust for the main direction to the average evidence of many observations.

Reliable evidence as to time would give the most conclusive evidence as to direction, but there is very little evidence available as to the time at which the earthquake passed different localities.

The time records are, however, not very consistent. The most precise record is that of the seismograph at the Coats Observatory at Paisley, where three slight earthquakes were recorded. Their times are recorded by Mr. Donald Maclean as 8 h. 53 m. 42 s., 9 h. 26 m., and 9 h. 30 m. 12 s. They were only tremors with amplitudes of ·15, ·2, and ·3 mm. respectively. (See Figs. 3 and 4.) The Glasgow earthquake was felt only as a tremor, which was by far the faintest of the three. The 9.26 and 9.30 tremors were more powerful, and they have been identified by Dr. Milne as due to an earthquake off the south-eastern coast of Africa.

The slightness of the Paisley record is surprising. There must have been an earthquake at Paisley at about 8.54 p.m., with an amplitude of more than a millimetre, for it was felt by many people; it caused the displacement of some furniture, and, according to the evidence collected by Mr. J. M. B. Taylor, split a block of stone at the insertion of an iron railing,

* J. Milne. "On 387 Earthquakes observed during two years in North Japan, October, 1881—October, 1883." Trans. Seismol. Soc. Japan, vol. vii., part 2, 1884, p. 5.

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cracked plaster, and threw door frames out of plumb. These effects are hardly likely to have been produced by a wave with an amplitude of only a tenth of a millimetre or $\frac{1}{250}$ of an inch. According to Dutton, an earthquake is sensible to the feeling if it have an amplitude of half a millimetre with a period of a fifth of a second. The smallness of the Paisley record may be appreciated from the comparison that the Tashkend earthquake of 4th January produced a movement on the Edinburgh seismograph of an amplitude of 29 mm., or nearly two hundred times as much as that caused by the Glasgow earthquake at Paisley.

The vibrations of the Tashkend earthquake at Edinburgh were, of course, slower, and the sensible shock depends on the combined amplitude and velocity.

It may be suggested that the boom of the Paisley seismograph was exactly at right angles to the earthquake wave, so that it was shaken but not displaced; but that explanation is inadequate, for the evidence shows that the wave must have traversed Paisley obliquely to the seismograph boom.*

The other time records indicate a disturbance at about 8.54. Professor Gray felt it at the University within a few seconds of 8 h. 54 m. 20 s. The most hopeful sources of reliable time records are the railway signal boxes, where the clocks are correlated, and a note is made of any unusual experience. Mr. T. W. Pettigrew, of the Caledonian Railway Company, has kindly sent me a note of the times at which the earthquake was noted at its signal boxes (see Appendix I.). The effect was described as "very violent" at Dawsholm, Maryhill, Maryhill East, Possil, and Springburn, the district which all the other evidence indicates as the probable source of the earthquake. The time is recorded as 8.54 in the area including Possil, Maryhill, Kelvinbridge, Partick, Partick East, Anniesland, and Paisley. Outside this area the time is generally recorded as 8.55, as to the west of Glasgow at Blackstone, Bishopton, Partick West, Scotstoun, and Scotstoun West and Bowling; also to the east of Glasgow at Springburn, Buchanan Street, Balornock, Robroyston, Germiston, Parkhead, London Road, Clyde

* Answers to subsequent personal inquiries show that the earthquake was less severe in Paisley than in Glasgow, and also less than in Renfrew.

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Bridge Steel Works, Cambuslang, and Rutherglen. The time was recorded at 8.56 at Stobcross.

Mr. J. C. Christie has kindly collected a record of the times on the various signal stations on the North British Railway. Mr. Christie states that most of the men who heard a rumbling noise in their signal cabins attributed it to the passage of a train somewhat heavier than usual, and that none of the electric instruments in any of the cabins were put out of working order by the earthquake. According to his report, the earthquake was felt at Bowling, Strathblane, and Blanefield at 8.54. It was felt like a distant explosion at Clydebank about 8.55; at the same time at Milngavie; and at Singer at 8.55 or 8.56. Further to the west it was felt slightly at Dumbarton, but the time there is uncertain. It was not felt at Cardross nor at Helensburgh. To the north and east of Glasgow it was felt at Kirkintilloch and Lenzie, but not at any other point eastward on the North British main line to Edinburgh, nor was it felt at Torrance or Lennoxtown.

The time records are not fully consistent, but it must be remembered that the difficulty, except in two cases, is due to a difference of a minute, and an error of a few seconds near the half-minute would lead to the inconsistent results. It seems most likely that the times are slightly too early at Blanefield and Strathblane, and that at Stobcross a minute or two late. The railway record at Paisley agrees as to the minute with that at the Observatory, which is probably some seconds too soon. Reference to the copy of the seismogram (Figs. 3 and 4), which I owe to Mr. Maclean, shows that determination of time can hardly be relied on within a few seconds. The slight inconsistencies in the time records prevent them throwing any certain light on the precise centre of origin. The earthquake time was probably some seconds after 8.54.

A map showing the homoseists is given as Fig. 5, and it points to the neighbourhood of Hillhead, Maryhill, and Possil as the epicentre.

Mr. Pettigrew's records show that a secondary earthquake was felt at 9.10 at Pollokshields, Langside, and at three stations in Cathcart. The shock at Dumbarton Junction was

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Fig. 5.

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recorded at 9 o'clock, and the only other record from Dumbarton gave the time as shortly after 9, so that Dumbarton was apparently outside the area in which the main earthquake was perceptible.

The general evidence points clearly to the district to the north of Glasgow between Bishopbriggs and Maryhill, and especially near Ruchill and Possil, as the locality where the earthquake started. It doubtless began along a fault, as was suggested by Mr. Macnair in an article in the *Glasgow Herald* of 16th December. A map which I prepared for a recent paper* shows that the longer axes of the areas affected by many of the British earthquakes trend from north-east to south-west; hence it was natural at first to consider whether the Glasgow earthquake might be due to a movement along a fault with this trend.

This view would be consistent with some of the time records. Thus, the earthquake was recorded at 8.54 at localities extending from Paisley north-north-eastward to Strathblane, and in intervening places from Bowling and Clydebank to the University. If the Blanefield time record be correct, it would suggest that the earthquake was due to movements along a deep-seated fault running from south-south-west to north-north-east from Paisley to Blanefield. The greatest extension of the earthquake area being east and west from Helensburgh to Glenboig might be explained as due to the more ready passage of the surface waves in that direction along the Corboniferous rocks of the Clyde basin or along the east and west faults. This hypothesis would, however, be inconsistent with the time records from Partick, Scotstoun, Clydebank, and Milngavie, and with the 8.56 record at Stobcross. The balance of the evidence seems to me opposed to the origin along a north-east to south-west fault. Mr. Macnair was probably correct in referring it to one of the faults that trend east and west across the Glasgow area.

The evidence available is most consistent with the epicentre of the earthquake being an area not more than 2 miles in length beside one or both of the two step faults which pass through

* "The Glasgow Earthquake of December 14th, 1910, in Relation to Mining." Trans. Inst. Min. Eng., vol. xli., part 1, 1911, pp. 55-63, pt. ii.

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Possil and Maryhill (Fig. 6). The southern of this pair of faults passes to the south of Possil, and further east it throws the Millstone Grit against the Coal Measure series near Gartloch and Gartcosh. The northern of the two faults passes through Maryhill and Colston, and further east it brings the Millstone Grit against the rocks of the Carboniferous Limestone series.

As the evidence was received it soon pointed to an origin somewhere between the faults between Maryhill and Bishopbriggs. I subsequently received striking evidence of a severe and vertical disturbance in that area. Thus Dr. Brownlee, of Ruchill Hospital, tells me that "the earthquake was felt all through the hospital, but nowhere produced any special directional effects. . . . In my own room the shock was fairly severe, but seemed to be absolutely vertical, as I have decorative plates resting almost vertically on ledges on each of the four walls, and there was no disturbance, not even as regards shaking."

The direction of movement at Colston, half a mile south of Bishopbriggs, was regarded as nearly vertical by Mr. J. M. Lindsay, who records his experience as follows:—"My wife and I were sitting reading when the shock came. There was not the slightest sensation of undulation, just a startling thud. We both said that whatever it might be the disturbance was immediately below us. So sharp and quickly past was the disturbance that we had no chance to see how anything in the room moved. So very distinct, on this occasion, was a downward movement that I looked rather anxiously next morning at the brick and rubble gable of the house; and if some one had authoritatively told me that the ground was several inches nearer to sea-level than before I should not have been much, if any, surprised.

"A second thud was also felt, but it was of the slight nature above referred to, so that if we had been moving about it would probably not have been noticed at all.

"I never thought of earthquake over a considerable area. The sensation was so very sharp—having a duration, I should think, of less than a second—that a feeling of merely local

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disturbance was experienced. The sound also gave an impression of nearness. The vibrations in air were not felt nor prolonged as in the case of an explosion at some distance. There was no rumble or reverberation. One could not distinguish between shock and sound, so quickly did the latter cease."

Mr. Lindsay, however, tells me that the experiences of a neighbour were not quite the same, as he heard an approaching rumble, apparently from south of west, and then felt the swaying of his bed on an east and west line, or perhaps between a little north of east and south of west.

As the neighbourhood of Possil was formerly an important mining centre, this position of the epicentre may appear to support the suggestion that the earthquake was due to a collapse of some old mining excavations. This view, however, seems to me impossible, as the earthquake must have originated at far too great a depth.

The Edinburgh earthquake of 18th January, 1889, was very similar to ours in range and intensity; it was felt over an area of 30 miles north and south by 26½ miles east and west; its intensity at the epicentre was No. 6 of the Rossi-Forel scale. According to Dr. Davison,* its probable focus was at the depth of about 8 miles. As the intensity in the Glasgow earthquake decreased more rapidly from the epicentre, the depth was probably less, but still it can hardly have been at a less depth than several thousand feet. If it had been caused by the collapse of mine workings it should have shown a rapid decrease in intensity near the sunken area, but the most marked fall in the intensity occurred about 2 miles from the probable centre.

The evidence from the fall in intensity is unfortunately too indefinite for Dutton's method of determination of the depth of the focus to give reliable results. The angle at which the earthquake emerged at the surface in Hillhead, as shown by the cracked plaster at the University, is also too slight for any satisfactory conclusion as to depth, even if that method were reliable. The evidence, however, so far as it goes, suggests that the earthquake originated from at least several thousand feet beneath the surface.

* C. Davidson. "Geol. Mag.," 1891, p. 66.

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The connection between the distribution of the shock and of the geological formations also gives interesting indications as to its probable depth. The earthquake as a sensible shock was practically confined to the sedimentary rocks of the Carboniferous Limestone series, and barely extended on to the volcanic rocks of the underlying Calciferous Sandstone series. Thus it was felt northward throughout the area of the Carboniferous Limestone series to Milngavie, and was noticed by occasional observers at Mugdock and Lennoxtown, but not on the Campsie Fells. At Barrhead it was faintly noticed on the lower slopes of the Fereneze Hills, but further to the south-west the records are confined to the Carboniferous Limestone series, along which it extended as far as Lochwinnoch. Its extension to that locality may have been due to the faults by which the Carboniferous Limestones have been faulted down between the Calciferous Sandstone lavas to the north and south (Fig. 1).

It may be suggested that, if the earthquake originated beneath the Calciferous Sandstone series, the various outcrops of that formation should have been more affected by it; but unless the earthquake originated below the Calciferous Sandstones it would have been started at the depth of less than 2000 feet, and that depth is inadequate to account for the widespread distribution of the shock in proportion to its limited strength at its epicentre. It must, therefore, have originated at a much greater depth, and its restriction to the Carboniferous Limestone series must be due to its more ready transmission through those bedded rocks than through the more compact and massive underlying lavas.

The question of depth is of some importance as bearing upon the suggestion that has been made that the earthquake was due to the overloading of the surface by the heavy buildings of this city; but if it originated at the depth of several thousands of feet the weight of buildings would have been comparatively insignificant, while the earthquake came from the north-western suburbs, where buildings are lighter and fewer than in the city.

The question of most general practical concern in regard to earthquakes is the probability of their recurrence, especially as to the likelihood of an area affected by a moderate shock

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being visited by one of a more mischievous kind. The slight earthquakes which have been repeatedly recorded in Glasgow will doubtless continue to happen at irregular intervals; but the evidence of the recent earthquake affords ground for the belief that they are not likely to occur with a serious increase of severity; for tectonic earthquakes are generally followed by a series of after-shocks due to the gradual readjustment of the ground after the main movement. There have been no after-shocks since the 14th December. It may fairly be inferred from their absence that the rocks underneath Glasgow are now so stable in arrangement that there is no probability of any earthquake here more serious than the moderate shocks which have been often felt, but have done little material damage.

Appendix I.

List of Signal Cabins on the Caledonian Railway and the various times at which the shock was felt—

8.54.	8.55.	8.56.	9.0.
Dalmuir.	Bowling.	Stobcross.	Dumbarton.
Kilbowie.	Scotstoun.		Bowling Swing Bridge.
Clydebank.	Scotstoun W.		
Yoker.	Partick W. Junc.		
Partick N. Junc.	Buchanan St.		
Crow Road.	Sighthill Station.		
Bellshaugh Junc.	Maryhill E.		
Kelvinbridge.	Springburn Park.		
Dawsholm.	Balornock Junc.		
Maryhill.	Germiston Junc.		
Paisley (St. James)	Blochairn.		
	Parkhead Iron Wks.		
	London Rd. Junc.		
	Rutherglen Junc.		
	Cambuslang.		
	Clyde Bridge Steel Works.		
	Bishopton.		
	Blackstone.		
	Robroyston W. Junc.		
	Possil.		

9.10.	9.13.	9.25.
Pollokshaws East.	Anderston Cross.	Milton.
Langside.		
Cathcart.		
Cathcart W. Junc.		

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Appendix II.—Summary of Correspondence *re* Earthquake of 14th December, 1910.

(Some of the letters deal with more than one area.)

	Time.	Sound.	Direction.	
I. Western District.				
1. Philips, Mrs. L. M., Cemetery Lodge, Dumbarton,	Shortly after 9.			
2. Story, Miss H., 30 Lilybank Gardens,				
At Rosneath,			E. to W. or N. to S.	
At Anderston,				Earthquake felt.
3. Sharp, J. H., Parkhill, Dalmuir,	8.54.	Explosion or fall of furniture above. Window rattled.		
1 mile north of Canal,				
Beside the Canal,				Not felt.
4. Ferrie, Robert (of 195 Crow Road, Partick), *re* S. Barr Estate,	8.54-8.55.	None except straining of walls.		Duration, 5-6 secs.
5. Miller, Thomas M., Sandycroft, Sandy Road, Renfrew,	Before 9.	None.	E. to W.	Duration, 2 secs.
6. M'Clelland, Rev. Robert, All Hallows, Inchinnan, Renfrew,		Rumble.	E. to W.	
7. Taylor, J. M. B., Laboratory of Science, 5 County Place, Paisley,				Collected many observations and records at Paisley.
8. Maclean, Donald, Coats Observatory, Paisley,				Seismograph records.
9. Dewar, Peter, Cross, Lochwinnoch,	8.54.			
II. Northern District.				
10. Fleming, T. L., 4 Kinnoul Terrace, Milngavie,	8.50-8.51.	Explosion or fall of furniture.		Felt as one shock; vibration under foot.
11. Learmont, R., Rockbank, Milngavie,		Noise like load of bricks.	S.E. to N.W.	
12. Reid, Col., Mugdock Castle, Milngavie,			S. to N.	Felt by a few.

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	Time.	Sound.	Direction.	
Western District—*continued.*				
13. Barns-Graham, Allan, jun., Craigallian, Milngavie,				Felt.
14. Smith, Miss A. L. Guthrie, Achnagowen, Killearn,				Not felt there.
15. Coubrough, John, Blanefield,	8.55.	Fall of heavy furniture.		Not felt in kitchen; severe at U.F. Manse.
16. Murray, Adam, Southfield, Lennoxtown,		Thud and then shake.	North-north-eastward.	
17. Davidson, Rev. W. S., The Manse, Lennoxtown,		Rattling of a stick.		Not felt.
18. Roberton, John S., 176 St. Vincent Street,			N.N.E. to S.S.W.	
At Lennoxtown,	8.55 clock stopped.			
III. Western Suburbs.				
19. Balfour, T. A. R. (*re* E. & N. of Victoria Park), 45 Bishop's Road, Broomhill,		No rumble but loud report like explosion.		
20. Drysdale, Wm., Southbrae Drive, Jordanhill,		Heavy fall below.	E. to W.	
21. Staig, R. A., 16 York Avenue, Jordanhill,	8.55.	Heavy but momentary.	N. to S.	
22. Reoch, J. W., 22 Montgomerie Street, Kelvinside,		Fall of furniture.		
Crow Road,		Heavy fall.		Like bed lifting.
Queensborough Gardens,		Fall of furniture.		Do.
Technical College,				Not felt.
23. ———, White Street, Partickhill,		Explosion and fall.		
24. Browne, John, 31 Rowallan Gardens, Partick,				
At Jordanhill,	9.	Noise above.		Not felt.
At Bearsden,				People fled from one house, but not felt in the next.

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	Time.	Sound.	Direction.	
Western Suburbs—*continued.*		Loud; fall of heavy furniture.		
25. Rogers, Mrs. H. J., 3 Lancaster Terrace, Kelvinside, W.,			E. to W.	Shift of petrol house.
26. Macfarlane, J. E., 2 Montgomerie Crescent,				Miscellaneous records.
27. Wordie, J. M., *re* Bardonald, &c.,				Door burst open, faces E. 30° N.
28. Collins, Charles M., Kelvinside Paper Works, Maryhill, At Highfield Farm,	8.54.	Rumbling noise and oscillation.	E. to W.	Two shocks; duration, 3 secs.
29. Baillie, Thomas B., 29 Polwarth Gardens, Hyndland,	9.28.	Noise of grinding stones.	N.E. to S.W.	Slight tremors.
30. Shaw, George C., 26 White Street, Partick,	8.54.		N.N.E. to S.S.W.	Swaying of lamp and movement of oil.
31. Stevens, Alex., 17 Dalnair Street, Overnewton,		Strange noise.		Bad shock; house heaved.
32. Meikle, Miss, 41 Blackie Street, Overnewton,	8.54.	Fall and rumble.	Westward.	Ground gave a distinct wobble.
33. Mackinnon, R., Weights and Measures Department, Town Hall, Govan,			N. to S.	
34. Hamilton, D., 18 Barrington Drive, At Drumgoyne Drive, Govan,				Cups thrown northward from a shelf east and west.
35. Rosie, J. G., Albert Street, Govan,				
IV. Hillhead and West End Park.				
36. Stevenson, Mrs. M., 24 Wilton Gardens,		Distant explosion.	E. to W.	Sinking of west end of room.
37. Stevenson, John G., 2 Doune Gardens,	8.55.		S.E. to N.W.	
38. Stewart, John A., 3 Carlton Gardens,	After 9.	Rumbling like cart of bricks.		Violent trembling.

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HILLHEAD AND WEST END PARK—*continued.*	TIME.	SOUND.	DIRECTION.	
39. Becker, Prof. L., The Observatory,	8.54 m. 30 secs.			Door north to south wall opened.
40. Macbeth, Miss Ann, Queen Margaret Hall,			N. to S.	Wave-like feeling.
41. Buchanan, W. A., 14 Hillhead Gardens,			N. to S. or N.E. to S.W.	Pictures swayed forward.
At 18 Bute Gardens,	8.55.			
At 5 Lilybank Gardens,	10.	Door slamming.		Less severe than at Bute Gardens; bells rung.
Re Fereneze Braes, Barrhead,				Reports record there.
42. Sloan, Dr. Hugh R., Sutherland Terrace.			N.W. to S.E.	
43. Paterson, Mrs. Janet S., 31 Kersland Terrace,		Heavy motor.		
At Belmont Church,		Fall of furniture.		
44. Watson, Miss M. A. H., Laurel Bank School,		Fall above.	N. to S.	Bottles fell.
45. Drummond, R. H. T., 7 Rupert Street,		Heavy train.		
46. Wright, R. H., 109 Great Western Road,			N. to S.	Cupboard door N. & S. opened Eastward.
47. Bost, T., 12 Burnbank Terrace,		Thud.		Pushed up.
48. Robertson, M., 114 South Woodside Road,		Fall of furniture above.	N. to S.	
49. Wilson, A. N. A., 9 Park Quadrant,		Fall of furniture above.		
50. Anderson, J. W., 23 Woodside Place,		No sound.	W. to E. or S.W. to N.E.	2 secs. duration.
51. Bryce, Mrs. Agnes D., 11 Woodlands Terrace,			N. to S.	Statue swayed Northward.

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	Time.	Sound.	Direction.	
V. Northern Suburbs.		Explosive.	S.W. to N.E.	
52. King, Robert, Strathview, Caldercuilt Road, Maryhill,				Doors swung.
53. Wright, Miss A. C., 26 Landsdowne Crescent,				
At Gairbraid Avenue, Maryhill,	About 9. and 9.15.			Do.
54. Brownlee, Dr. John, Ruchill Hospital,				Vertical effect.
55. Lindsay, J. B., 166 Buchanan Street,				
At Colston, S. of Bishopbriggs,		Sound and shock together.		Vertical effect less than one sec.
56. Boyle, J., jun., 24 Forth Street, Port-Dundas,	After 9.			Felt.
VI. City.				
57. Frame, W. A., 1 Ford Place, Finnart Street, Greenock,	9.30?	Explosion.		
At Theatre Royal,				
58. Smellie, W. R., Mayfield Villa, Mossend,			N. to S.	Topheavy objects thrown northward.
At Messrs. Dykes Brothers, 11 Royal Exchange Square,				
VII. South of Central Glasgow.				
59. MacBrayne, John, 72 Houston Street, S.S.,		Sound after shock.	N. to S.	3 secs. duration.
60. Barr, M. G., 20 Apsley Place,		Fall on roof.		
61. Wallace, Matthew, 19 Keir Lane, Pollokshields,	8.54.	Fall in lobby.	W.N.W. to E.S.E. or *vice versa*.	Two motions.
62. Maclaren, W. B., Willowbank, Giffnock,	8.54.	Rumbling heard.	S.W. to N.E.	Bed heaved.
63. Watson, G. C., 478 St. Vincent Street,				Material thrown.
At Giffnock Quarries,	9.26.		N.E. to S.W.	

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South of Central Glasgow—*continued.*	Time.	Sound.	Direction.	
64. Black, E. A. T., Aldouran, Newlands,	About 9.		N. to S.	Photo and ornaments fell Southward from North mantelpiece; billiard ball moved S. 30° E.
65. Donaldson, Alex., 67 Durward Avenue, Shawlands,		Noise with rocking.	N.W. to S.E.	Dishes rattled and gazogene rocked.
66. White, Robert, 279 Holmlea Road, Cathcart,	9.20 or 9.25.	Concussion on roof.		8-10 secs. Ceiling cracked in every direction.
67. Wood, David J., 46 Phannan Road, Cathcart,	8.54.	No noise.	N. to S.	Vibration of trays; not heard by others.
68. Gartshore, Alex., Duntulean, Cathcart,	About 9.	Thud.		Screen fell; not recognised as earthquake.
69. Hay, John, 130 Stanley Street, Kinning Park,		Loud thud as of a heavy fall.		Upstairs heard nothing.
VIII. East of City.				
70. Alexander, Rev. John, Chaplain's Room, H.M. Prison, Duke St.,		Loud rumbling.	W. to E.	East wall swayed Eastward.
71. Smeal, W. G., 117 London Street,		Noise below.		Not heard nor felt near by.
IX. South-Eastern District.				
72. Hardie, G. D., Clarkston, Busby,		Rock blasting.	N.W. to S.E.	Heavy vibration.
73. Leslie, William, Jessamine, East Kilbride,	8.55.			He noticed it, but Mrs. Leslie did not.
74. Wallace, James, Wistran, Douglas Drive, Cambuslang,		Like explosion or dull thud of fall above; sound same time as shock.	N. to S.	
75. Macpherson, Edward, Ardleven, Stewarton, Cambuslang,			N. to S.	Ornaments inclined.

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South-Eastern District—*continued.*	Time.	Sound.	Direction.	
76. Boyle, R., Fernlea, 8 Parkhill Drive, Rutherglen,				
Re Burnside, Rutherglen,		Like fall. Heard in town.	E. to W.	
Giffnock,				West door opened.
Technical College,		Blow on roof.		
X. Eastern District.				
77. Gray, Mrs. Jane W., Commercial Bank House, Kirkintilloch,	About 9.	Fall of furniture.		Not heard close by.
78. Lawson, L. B., Ashfield, Kirkintilloch,	8.42.	Noise of quivering wall.	To North-Eastward	
79. Haeger, C., Presbytery, Glenboig,	About 9.			Tremor.
80. Smith, Miss Tina, Glenfarg, Stepps,	Just before 9.		Eastward.	
81. Warrall, George, 6 Buchanan Gardens, Mount Vernon,	Before 9.		W. to E.	2 shocks 2 secs. apart not felt near by at N. Mount Vernon.
82. Outhill, W., Beechwood, Uddingston,	Before 9.			Vigorous tremor felt by a few.
83. M'Gowan, Frank, Swinton Tavern, Easterhouse,	9.46.	Bump.		Shiver; plates jingled.
X. Miscellaneous.				
84. Morton, Dr., Town and County Club, Ayr,	6.45-7.			Tremor.
85. Pettigrew, T. W., Caledonian Railway,	Times at various Signal Cabins.			
86. Christie, J. C., North British Railway,	Do.			

Further evidence as to the distribution was given in the Glasgow papers from 15th to 17th December.

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New Channel eroded by Flood, Derry Burn.

From Photos. by J. W. Reoch.

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No. VI.—The Recent Floods in Perthshire: Their Geological Lessons. By Peter Macnair, F.R.S.E., F.G.S., Joint Hon. Secretary.

[Read 13th April, 1911.]

About one o'clock on the afternoon of Wednesday, 24th August, last a thunderstorm broke over the upper part of Strathearn, which was accompanied by such a downpour of rain as had never been witnessed before even by the oldest inhabitants. The storm lasted for over three hours, and it was during that period that all the phenomena about to be described took place. The exceptional character of this flood lay in the fact that a greater body of water had come down in a given time than had ever been known before. The rain came on suddenly, and for a period of three hours was excessively heavy. Eye-witnesses have described the burns as advancing with a great front or leading wave. This seems to have been the case, and it seems probable that it accounts for the almost universal belief that a water-spout had burst high up in the mountains. The volume of water that descended the various burns was undoubtedly very great, but all the damage seems to have been done within the three hours just mentioned. During the period of the storm both the denuding and transporting powers of the streams were increased to an alarming extent.

Sron Mhor is the name given to the elevated ground which rises to an altitude of 2203 feet on the north side of Loch Earn, and lies between Glen Beich and Glen Tarken. The total gathering ground of the area may be estimated at about 18 square miles. The two streams which bound the district enter Loch Earn, the Beich at Dalveich and the Tarken near Glentarken. Between these two streams five smaller streams descend the side of Sron Mhor between Ardveich and Derry. The solid rock of the mountain consists almost entirely of the typical mica schist so extensively developed in this part of Highland Perthshire. The boundary of the main mass of the solid rock may be taken as roughly coinciding with the 1500 feet contour line, the remaining and lower part of the area being covered by the more recent glacial deposits, which are principally represented by moraine materials formed of sand, gravel,

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and large boulders. By far the larger part of the stream courses have been cut through these glacial deposits, and in most cases have reached the underlying solid rock. Fragments of boulder clay or ground moraine, which was laid down during the period of maximum glaciation, occur at considerable elevations, and in some cases attain to a considerable thickness. For instance, in Glen Beich there is a large area of boulder clay at an altitude of over 1000 feet. A vast portion of this deposit must have been removed during the later or valley glaciations by the local glaciers, as fragments are found to exist above the limits of the valley moraines, the latter resting directly upon the solid rock of mica schist. The Allt Na Sac, or, as we shall call it here, the Derry Burn, rises almost exactly at the junction line of the protruding solid rock and the glacial deposits, and has a straight course through the latter formation for the distance of three-quarters of a mile.

The Lochearnhead and Crieff Railway cuts across all the streams under consideration, and at a lower level the main road between these two places is carried by bridges over the streams. On the day of the flood the Derry Burn came down from its source in the hills, swerving neither to the right nor left, but making straight as an arrow for the bridge over the railway. The water was of a dark colour, and was loaded with sediment. According to eye-witnesses, the ground seemed to tremble as if affected by an earthquake, and every now and again huge boulders came in collision with each other, making a noise like the sound of distant artillery. Near the bridges over the road and the railway, the stream having become constricted, piles of boulders and sand were accumulated. At these obstructions the water rose high into the air, tossing about huge tree trunks and boulders as if they were pieces of straw. Below the railway bridge, and between it and the roadway, was the special scene of havoc and disaster. Close to the railway is the farmhouse of Derry, situated about 230 yards above the level of the loch. From behind the farmhouse and skirting the Derry Burn a cart road leads in an almost straight line to the main road near the shore of Loch Earn. From the railway bridge to the main road the stream forsook its old channel, and in the short space of three hours the waters, sweeping onward to right and left,

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ate away the ground composed of large boulders and gravel, in an almost incredibly rapid and irresistible manner. An attempt was made by the occupants to stem the flow of the torrent by the piling up of large stones across its path, but this was entirely unavailing, as they were also swept away. The torrent seems to have chosen the cart road as the easiest way to the loch, for the new bed of the stream follows closely the track of the old cart road. The new channel is over 200 yards in length, with a breadth of from 6 to 9 feet and a depth of from 4 to 6 feet. The old cart road lay through a hayfield, and in some cases the stacks of hay were so situated on the verge of the new channel that they had to be propped up to keep them from falling into it. At this point the waters of the burn spread over the hayfield, carrying with them huge boulders, and spreading them over an area of close on an acre. I calculated that some of the boulders must have been little short of 3 tons in weight, while many hundreds would weigh from 1 ton to 2 tons.

Where these burns run beneath the railway the level of the streams has in some cases been artificially sunk, and the line crosses the stream on a level with the burn a little way up. This forms a sort of trap in which tons of boulders were accumulated during the flood, and as a consequence the waters overflowed the railway embankment to a considerable depth. For several nights and days a gang of surfacemen was stationed near the bridges to be ready to clear out any accumulation of boulders that might impede the passage of the water and again flood the railway. Where the torrent in its mad course reached the main road it spread over it for a distance of 30 yards, completely burying it beneath a mass of débris similar to that already described. This huge mass of boulders and gravel varied in thickness from 3 to 5 feet, and entirely obliterated the dykes and gates on each side of the road. So powerful was the rush of water that the bridge which spans the road at this point has been crushed and pushed for some distance towards the loch. Similar phenomena, though not on such an extensive scale, took place at the mouth of a burn about a mile further down the loch. One of the notable features of the Beich Burn is the prominent cone of detritus that has been

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formed by it where it enters the loch. A great addition to the extent of this cone must have been made within the last few days, as the Beich has been carrying down a heavy load of sediment and stones, and was seen to project itself far into the loch.

The great lesson which these floods have to teach the geologist is that during the storm the denuding and transporting powers of these streams were raised to an enormous extent. The Scottish school of geology not only founded, but has always been a zealous supporter of, the doctrines of uniformitarianism. But though we are forced to recognise this doctrine as a grand principle, yet beyond certain, though perhaps narrow, limits it has its exceptions, and the recent floods may be taken as a striking example of these. It is undoubtedly the continual dropping of water that has been the most potent factor in the destruction and reproduction of the solid land. But such floods as have just occurred in the Highlands clearly demonstrate that in such loose, incoherent deposits as boulder clay, sand, and gravel a flood of three hours' duration may work as much havoc as the ordinary course of the denuding agents may require many years to accomplish.

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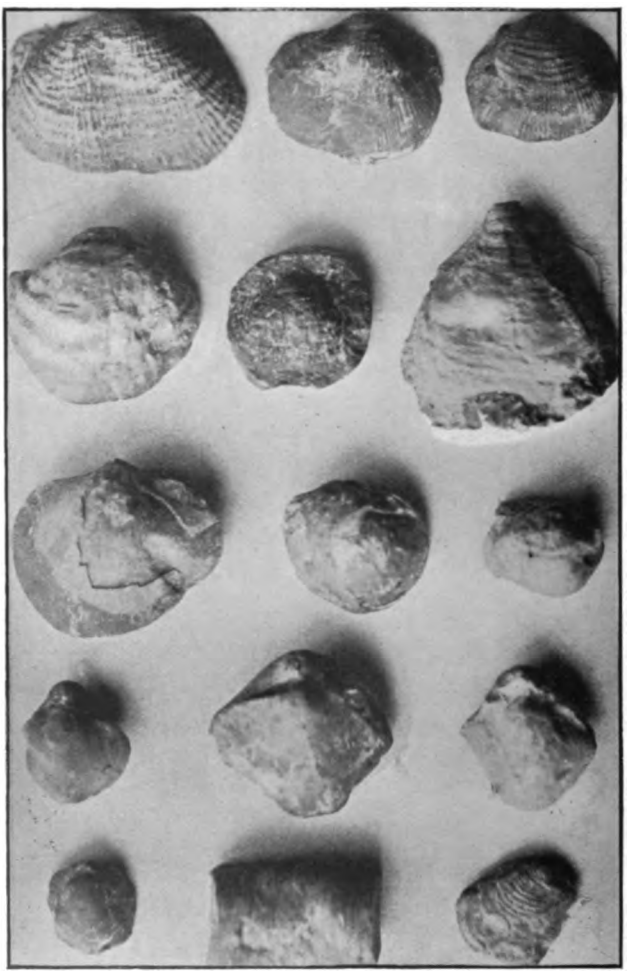

Diseased Fossils.

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No. VII.—Carboniferous Limestone Rocks of the Isle of Man.

By John Smith.

[Read 11th May, 1911.]

Introduction.

Many writers have taken notice of the Carboniferous Rocks in the South of Man, including Macculloch (Western Islands, 1819), but it is to Cumming (1846-1854) that we owe the first detailed description of these strata, with a pretty extensive list of fossils.

The Survey Memoir of Man, published in 1903, goes pretty minutely into the subject of the Carboniferous Limestone, and contains an extensive bibliography, Surveyor Lamplugh having given full details of all the Manx rocks.

My object in visiting the island was to collect a series of the Carboniferous Limestone fossils for comparison with those of the South and West of Scotland, to see if any relationship could be established between the two, and for this purpose I hammered at the limestone for ten weeks.

Cumming's section of the Manx Carboniferous Limestone Rocks is as follows, reading downwards:—

Posidonian Schist.
Poolvash Limestones.
Lower or Castletown Limestones.
Basement Conglomerate.

In the heart of the Poolvash Limestone there is a thin series of "Posidonian Schist," as we shall see further on, and in the Volcanics a few bands of limestone, the complete section of the Manx Carboniferous Rocks being as follows:—

5. The Volcanics, with interbedded Carboniferous Limestone and shale.
4. Posidonian Schist, composed of limestone bands and shale.
3. Poolvash Limestones, with interbedded "Posidonian Schist."
2. Lower Limestones.

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1. Basement Conglomerate, with Carboniferous fossils.
Unconformity.
Manx Slates—on edge.

PORT ST. MARY.

The Carboniferous Inlier here consists of well-bedded limestone of the lower series, the bands never reaching to a yard in thickness, the dips being gentle, generally towards the S.W., but curving up near the outer harbour wall to steeper angles. These strata are faulted against the Manx Slates, the best exposure for this being just at the S.E. horn of Perwick Bay, where the dip of the limestone is *towards the fault*, just the opposite of what we should expect it to be. This fault is probably of no great throw, as the Basement Conglomerate is seen not far from it.

Lamplugh (Sur. Mem., p. 205) estimates the limestone of Port St. Mary at 81 feet thick. Some of the bands have got a fairly even surface, others are exceedingly lumpy (Fig. 1), the swellings being sometimes caused by stools of *Lithodendron* and *Syringopora*, or masses of rugose corals, but being often segregated nodules of limestone. The colour of the limestone is generally pale grey, sometimes dark grey.

Monticulipora (*Chætetes*) *tumida* is abundant on certain bedding plains, well-grown and beautifully preserved, sometimes showing the rounded ends of the branches and cup-shaped hollows, a well-directed blow of hammer and chisel often exposing a longitudinal section of it, which is far more instructive than a polished one. It does not appear to differ in any way from the *M. inflata* of the Solway. *Zaphrentis* (*Campophyllum*) *cylindrica* is not so abundant here as we shall meet with it further on. It is also a Solway species. *Lithodendron affine* and *L. martini* occur in strong clumps, as does *Syringopora ramulosa*. Stalks of sea-weeds, often over an inch thick and several feet long, sometimes with a few branches, are common in certain layers. A big list of fossils cannot be obtained from these beds, and those observed will appear in the general list.

The Basement Conglomerate is not now to be seen above low tide, but, as it was noted by Macculloch, it must at one time

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Fig. 1.—Surface of a Limestone Bed, Port Saint Mary.

Fig. 2.—Syringopora.

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have been visible, and the Survey record two spots where it has been noted, both below low tide; so that the Port St. Mary strata must be near the base of the series as developed in Man. Occasional quartz pebbles are seen in the limestone, and parts are crowded with small ones.

The Manx Slates appear in the harbour close on the fault, have got a bluish, silky appearance, and are of the argillaceous type known as Barrule Slate.

Bay of Carrickey, from Centre of Bay to Balladoole Fault.

The Kentraugh boundary fault (which crosses under the water from Port St. Mary) comes out from below the waves at the head of the bay (middle part), and again the bedded limestone is seen faulted down against the slates of the Black Rock, and extends along the shore for about a mile, until truncated against the Balladoole Fault, a nearly N. and S. fracture which has brought down the massive Upper Limestone (lower part) of Poyll Vaaish against the lower bedded series. Here we again meet with the large *Zaphrentis*, a specimen measured being 43 inches long, and magnificent clumps of *Syringopora* (Fig. 2), and the broad form of *Productus giganteus* 8 inches across. Masses of *Lithodendron* occur in an inverted position, showing that the sea bottom was at times swept by currents, or agitated by the waves. At this part of the coast the limestone is mostly under high-water mark, and fine specimens of corals are often seen on the smooth surfaces of the beds.

Opposite Balladoole Smithy, and South of it.

As already remarked, the Upper Limestone is brought down against the Lower Limestone by the Balladoole Fault, and here the limestone is much dolomitised, and E. and S. of the gravel spit called Poyll Ritchie the dolomitisation continues in a patchy manner for about 2 furlongs, and occupies the tideway for as great a width, the altered patches being often surrounded by limestone and parts of the limestone by dolomite. The bits of limestone in the dolomite are often very small—an inch or two—but sometimes as large as 20 yards across, and these

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often show strings and isolated (in plan) lumps of dolomite. Between the limestone and the dolomite a softened material sometimes occurs of a brownish, yellowish, or cream colour, and is at parts prolific in fossils, but sometimes rather barren of them, the richest fossiliferous bits being E. of Poyll Ritchie, near the old smithy. Some of this stuff is pretty firm, and the beautiful specimens in it crack out readily; other parts are quite soft and the fossils tender and often "chalky." The area near the smithy has got a lot of this material, always in hollows between harder bits of limestone and dolomite, and it has to be dug for in the tideway, this part being prolific in gasteropods (which, of course, also occur in the harder limestone here as well), there being at certain places plenty of cephalopods, including large and small goniatites, brachiopods, occasional corals, &c. How this softening of the limestone came about is not easily understood, but it is evidently (in part) just an arrested phase of the dolomitisation, completed probably by the action of acidulated rain water when the land stood higher during the Peat period (see p. 139).

Some of the soft material, where it assumes the chalky state, may be washed for microzoa.

A peculiarity of some of the soft material is that at parts a thin skin of it has taken an appearance not to be distinguished from the ordinary grey limestone. It has been said that the dolomite is "defossilised," but this is too sweeping an assertion, as parts of it contain plenty of fossils, although other parts appear to be devoid of them.

A cursory run over certain parts of the dolomitised area might induce a geologist who had stumbled upon it for the first time, and was ignorant of the literature of the subject, to write it down as lava, and the limestone as lumps which had fallen into a volcanic vent, so closely does the dolomite simulate lava, and the weathering along its joints rhyolitic flow and slaggy structure. When I came to it at first I found an English doctor on the spot, and he explained it to me as "a volcano," and from anything I could see at the moment I was not prepared to contradict him. Subsequently he informed me that he studied no kind of rocks but the volcanic, and that he had not begun geology till he was over sixty years of age.

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In this part there is a thin conglomerate of rolled crinoid joints, shelly débris, and occasional pebbles of limestone.

Another peculiarity of the limestone in this area is that parts of it have been altered to calcite, and this evidently took place during the dolomitisation stage, the calcite being often in the softened stuff, but also in the hard limestone and in the dolomite as well, its boundaries being very irregular and always rounded. It looks at a first glance as if the calcite had been deposited in hollows previously made in the limestone; but fossils, though scarce, occur in it, which seems to forbid that interpretation, so that this quality of calcite looks to have resulted from limestone altered *in situ*. The largest patch of calcite (no fossils seen in it) I observed occurs towards the south of the area, well down in the tideway, and at a part where the limestone has been worn pretty flat, and is free from sea-weed. It measures 15 feet by 6 feet at widest part, is touched by two small masses of dolomite, that substance also occurring in its cleavages, which lie at many angles, and are particularly bright, the largest cleavage face seen being half a square foot in area. Not far from it a mass of quartz 6 feet in diameter occurs in the limestone, and has strings of dolomite passing through it.

Alongside of the Balladoole fault silica is often seen, taking a beautiful reticulate structure in the dolomite, the white quartz contrasting strongly with the dark-brown dolomite. Here there are also patches of carbonate of iron, which weathers first to a dirty brown and then to a soft dirty yellow.

To obtain fossils readily from any limestone it appears that it requires to have got a certain amount of weathering. The little tideway stacks of limestone in this area often rise above high water, and, where liberally broken up by weather cracks, often, but not always, yield a lot of fossils. An ordinary hammer makes little impression on them, but by using a collier's pick a few hundredweights may be torn down, or, if the stack is a small one, demolished altogether to the solid limestone below, which, even if it could be removed readily, would yield few fossils, as when broken the fossils mostly break across with the stone. The fossils obtained towards the south of the area are generally brachiopods, but spirals, bivalves, and

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cephalopods also occur, and, although crinoid débris is sometimes abundant, determinable parts are seldom seen.

The Poyll Ritchie area, and S. of it, is probably on a lower horizon than the area to be described next.

Lamplugh's opinion that the dolomitised areas 100 yards E. of Balladoole fault, and further, are parts of flaggy beds that once surrounded "knolls" of light-coloured limestone (Sur. Mem., p. 212) is not borne out by the fossil evidence.

Poolvash.

Opposite Poolvash Cottage (S.E. of the dolomite area) the two first "knolls" of the light-grey Poolvash Limestone (Fig. 3) occur just above the beach, and, although containing fossils, these do not break out readily. I expended a considerable time on them without adding much to my stock. Immediately S. of these knolls massive limestone rests on bedded limestone (this section being illustrated on p. 213 of the Sur. Mem.), some lenticular bands occurring in the bedded part. Fossils may be obtained here, but immediately S. of this the most fossiliferous limestone begins and continues to what may be called the

Goniatite Ridge,

situated just to the N. of Ghaw Gortagh, a small inlet of the sea, mostly dry at low tide (see plan, Sur. Mem., p. 211), the ridge extending nearly from the notch of the raised beach down into the water. The limestone is massive, but certain lines in it indicate a southern dip, so that the beds just to the N. of the goniatite ridge will be on a lower level than it. They are exceedingly fossiliferous, and not without goniatites; orthoceratites and bivalves are common, but spirals are scarce. This small area is certainly the richest fossil spot in the Isle of Man, and the place to which the hammermen always gravitate.

Along the N. margin of Ghaw Ghortagh black shales appear, and just at the N.E. angle of this little bay platy shale may be obtained, which contains abundance of *Posidonomya becheri*, along with its accompanying cephalopods, bivalves, *Fusulina*, and ferns. The material must be sought for under masses of putrid sea-weed, and here the collier's pick is invaluable. These

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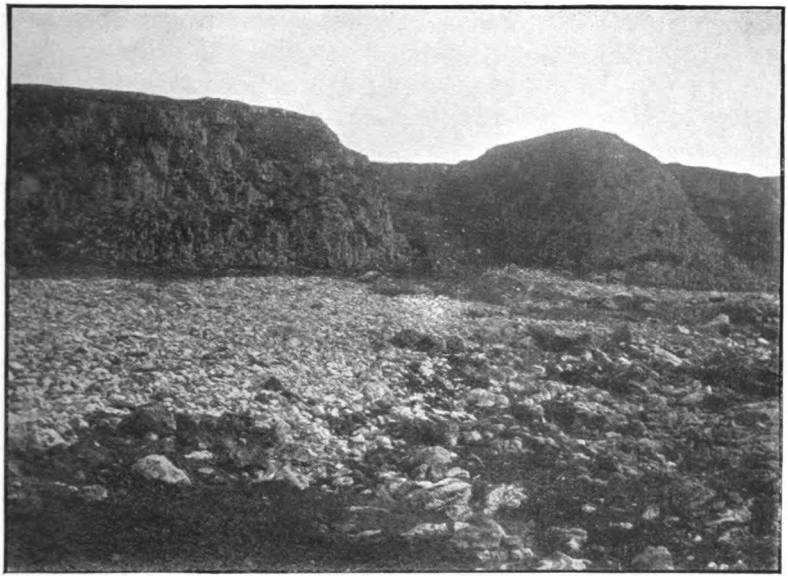

Fig. 3.—Limestone Knoll.

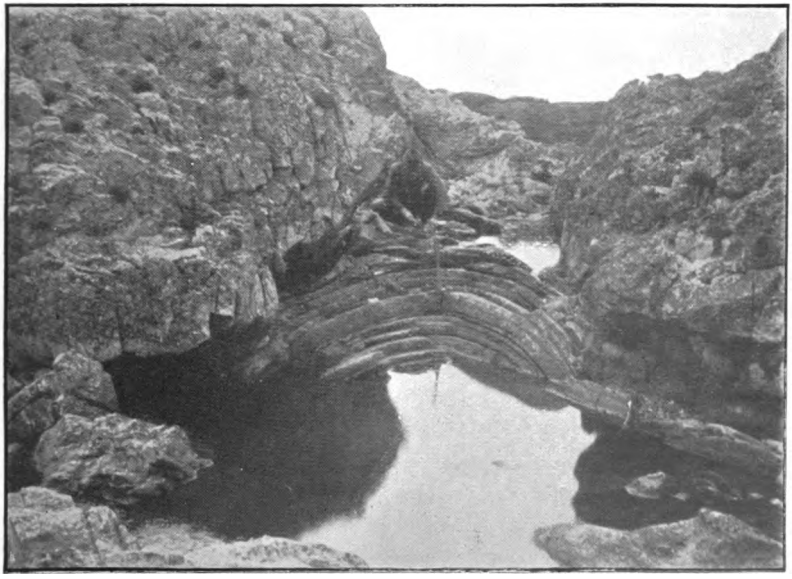

Fig. 4.—Anticline of Posidonian Schist, in Poolvash Limestone.

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black shales rest on what has been called the Conglomerate Bed, a band up to 2 feet in thickness (occurring also above the shale), made up of limestone pebbles, bits of shale, and containing a few fossils. The Conglomerate and Posidonomya Shales are embedded in the Poolvash Limestone (see introduction), the shales having much the same appearance as some of the black beds above the limestone, and containing much the same kind of fossils. Opposite Poolvash farmhouse they are beautifully seen in the tideway, having been thrown into anticlines (Fig. 4) and synclines. Cumming thought that they (the black beds) had been deposited between "knolls of limestone," having probably been led to this conclusion by the conglomerate bed which occurs below them, but a study of the black beds will not bear out this contention, as the basset edges of the outcropping bands of the black beds are of the full thickness where they are seen to climb the sides of the knolls, showing that they once covered the limestone in level courses, and were curved up when the limestone was deformed by earth movements. Had Cumming's interpretation been the right one, the black bands ought to have tapered off against the knolls. The deforming agencies had been of no great intensity, just enough to curve up the beds, and it is only occasionally that we see a fossil out of shape.

The impure-white limestone which occurs above the black bands is of very different fossil value to that below them. It is massive, and so metasomatised that fossils are not often seen in it. Several knolls of it occur both inland and along the shore, the last of them rising prominently above the beach N. of the old Black Marble Quarry. At spots where they are extra well weathered a few fossils may be obtained, mostly *Producti*.

Cumming came to the conclusion from a study of the fossils that the Poolvash Limestones had been deposited in a rather shallow sea (Guide, p. 161). We have seen from the Ghaw Ghortagh Conglomerate and the rolled fossil débris E. of Poyll Ritchie that the sea at times must have been pretty shallow, and right in the heart of the Poolvash Limestone, below the interbedded black shales, I saw a mass of *Lithostrotion portlocki*, which had been turned upside down. It is also quite a common

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thing in breaking up a mass of fine-grained limestone to find an absolutely perfect fossil inside of it, and fossils like this had certainly not lain long on the sea bottom before being covered up. These facts point to the conclusion that during the deposition of the limestone in this area there were currents bringing limey mud, sealing up the shells, &c., and so preserving such a fine series of fossils.

Some of the massive limestone when struck gives off a strong odour of petroleum; and in the area described under the heading "Poolvash" no dolomite patches were seen.

Posidonian Schist.

Poolvash Black "Marble" Quarry and Tideway opposite it.

The strata here form the most southern part of the limestone area, and are, with the exception of a few bands in the Volcanics (see p. 119), the highest beds of limestone in the Isle of Man. This black series measures 24 feet, and appears to have been laid down in a *putrid sea*, where abundance of organic matter was constantly decaying, and doubtless these strata are connected with those imbedded in the impure-white limestone at a point where the upper part of the latter tapers off, the fauna of the two black horizons linking them together.

The black limestone was at one time quarried as a "marble" and building stone. Good exposures can be examined both on the beach and in the old quarry, and are seen to be well bedded, a quality necessary in a limestone raised for building. When these strata were being quarried doubtless fossils would be obtained in some plenty, but at present it takes a lot of hammering to get a few specimens.

In the tideway some peculiar drumlin anticlines can be examined. They bulge up from the general surface of the beds in elliptical swellings, and look like the backs of fossil whales. They appear to be too good for natural productions, but are perfectly natural, though difficult to understand and interpret.

Cumming's contention that the Posidonian Schist was deposited between "knolls of limestone" is at first supported by Lamplugh (Sur. Mem., pp. 221-2), but he wavers a little

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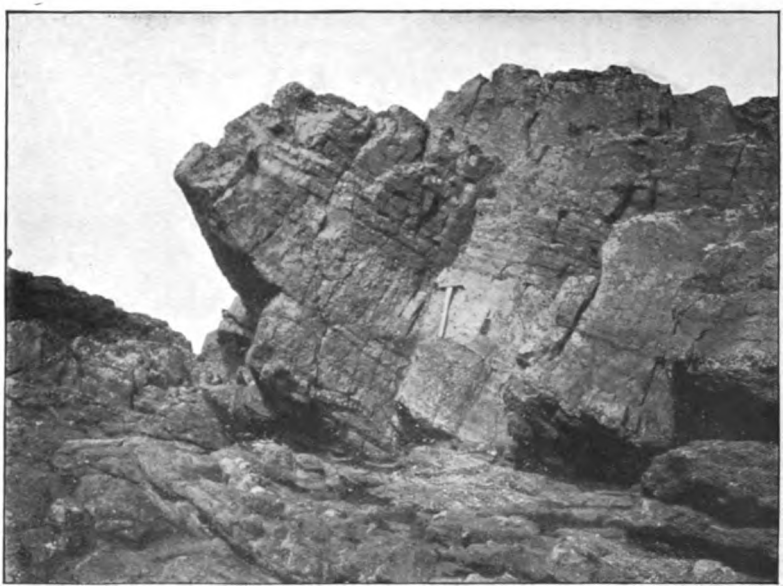

Fig. 5.—Vesicular Rhyolite.

Fig. 6.—Pillowform Lava.

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on this point by-and-by (p. 248), and if this had been the case the Posidonian Schist ought to have tapered off against the knolls, as already explained.

The Volcanics.

Proceeding southward along the coast we come, at a length of not many yards from the old quarry, to the Volcanic Rocks, resting on the Posidonian Schist and extending to Scarlet Point, a distance of a mile. These rocks were a great puzzle to the earlier geologists. Berger, in 1814, called them "amygdaloids"; Macculloch (1819) considered them to be "breccias"; Henslow recognised their true nature as "volcanic ashes"; and Cumming called the material "marine tuff," a designation which later geologists have not been able to improve upon. They consist of both massive and well-stratified beds; at parts stones are absent or rare, at others abundant, and reach the dimensions of blocks several feet in diameter. The stones are angular, sub-angular, and well rounded, the latter having evidently rattled up and down the vent of a volcano many times before being finally thrown out. The most abundant kind of stone is a light-coloured amygdaloid, with rounded amygdules, and this quality of rock had evidently—during the volcanic episode—consolidated in a volcanic vent repeatedly, and got broken up and blown out by explosions. Deprived of its exfiltration in-filling, it would form a light pumice, but it is not apparent whether the in-filling took place in the vent, or after it had become embedded in the peperino. Limestone blocks and stones are not uncommon in parts of the ash, and some of them were doubtless derived from the limestone strata (the Volcanics being above the Limestone), through which the volcanic vent pierced, but it is not unlikely that limestone may have been deposited in the crater or throat of the volcano and got blown out during eruptions. There is no evidence that any part of the ash beds were ever above sea-level, no remnants of ancient soils, forests, or even fragments of wood having been seen in them. Felspar crystals separated from the liquid lava by explosions occur in the ash.

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Stratified Fossiliferous Rocks in the Volcanic Ash.

At Close ny Chollagh the ash beds contain thin bands of limestone and shale, and irregular bands and nodules of black chert, and not far above their base, 100 yards S. of the Old Fort, I measured a bed of limestone 7 feet thick in the ash. It is grey limestone, shows no breakages, tapers off in both directions, and looks exceedingly like as if it had been deposited where it now rests. About the middle of the area, near high water, a drumlin anticline of limestone is seen bulging up from under ash, but whether it represents part of the Limestone (Posidonian) series, or is embedded in the ash, cannot be made out. There are other stratified bits of limestone and shale in the ash, but they need not detain us.

Surveyor Lamplugh is of opinion that some of the limestone strata were dragged from below into the ash by thrust movements, but is prepared to admit that other parts of it were undoubtedly contemporaneous with the deposition of the ash, so that the highest authority on Manx Geology has confirmed the opinion of the most classical authority that the ash beds are composed of "marine tuff" (Sur. Mem., p. 234).

Fossils in the Ash.

In the limestone beds in the ash fossils may be seen—corals, shells, and sea-weeds, or sponges; and in the ash itself a few have been got—*Sphenacanthus*, goniatites, crinoid débris, &c., —but they are exceedingly rare, and after making several traverses along the whole outcrop of the Volcanics I failed to find a single specimen.

In 1892 Surveyors Strachan and Lamplugh mapped the Volcanics on the 25-inch sheet, and certainly the 1-inch representation gives but a poor idea of this remarkable area, which, along with the Poolvash and Balladoole limestone and dolomite, a casual visitor has remarked, "ought to be put in a glass case."

I observed particles of volcanic ash in the Posidonian black shales, which may indicate that the volcanic energy broke out at a distance before it reached this area.

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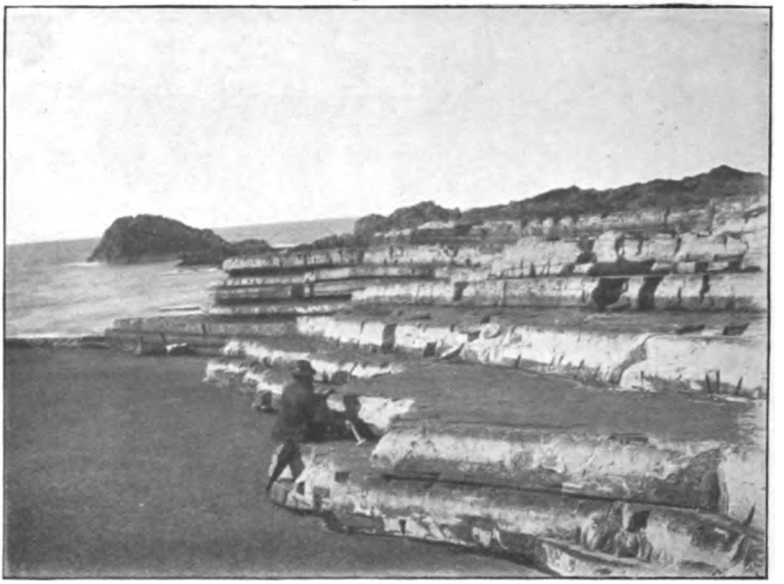

Fig. 7.—Bedded Limestone—Stack of Scarlet (in the distance).

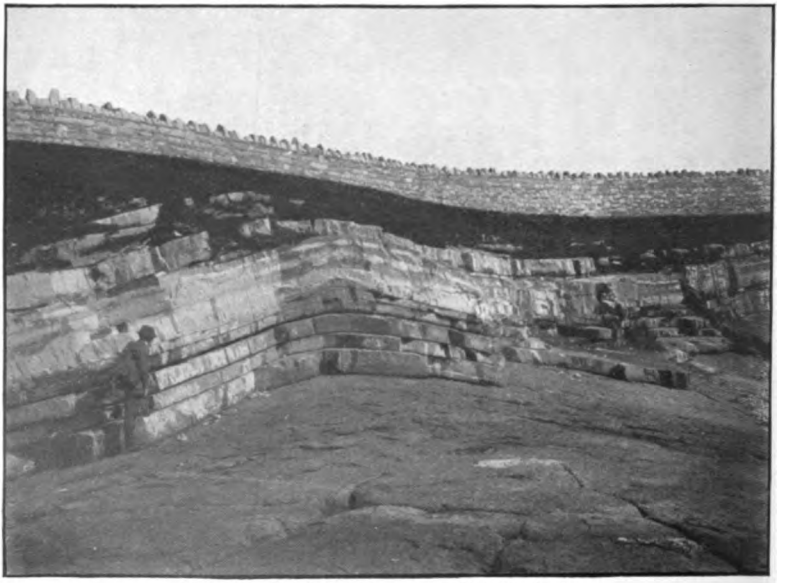

Fig. 8.—Folded Limestone, Scarlet Point.

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Solid Igneous Rocks in the Ash.

From near the Stack of Scarlet westward "ridges" of igneous rocks occur, projecting considerably above the ash. These have been described as "dykes" and as "sills," but Lamplugh considers them to be "lava flows" dragged somewhat out of their original positions by earth movements, and the fine examples at Cromwell's Walk, 340 paces N.W. of the Stack of Scarlet, seem to the casual observer to confirm this opinion. It is a magnificent, vesicular rhyolite (Fig. 5), every feature prominent, and viewed from a short distance looks just like a stratified rock. The flow structure dips at nearly every angle, from almost horizontal to perfectly vertical, and this is one of the most remarkable examples of a solid igneous rock I have ever seen. At present it rests on a very coarse agglomerate of stones, and bits of ash and stones have been caught up in the bottom part of it. One's first impression is that it is a sub-acid lava flow that in cooling had been shoved on from behind by the lava following, and got considerably ill-used in a remarkable manner. It shows few breakages, so that the bending evidently took place when the lava was in a soft state.

A lava flow having a pillow-form structure (Fig. 6) occurs in the ash a little S. of where the thick limestone bed is seen in the ash.

Stack of Scarlet.

This is the most prominent feature of the Volcanic area, the stack (seen in Fig. 7) occurring as a tidal rock completely surrounded by water at full tide. It can be easily ascended, and appears on its N. side as a massive dolerite, with a few prominent crystals. On its top it has got a "platy structure" (Lamplugh), and its S. side is columnar, the columns being nearly vertical and the platy structure passing through them. Before I had read Lamplugh's description I had written down the platy structure as of rhyolitic origin, and caused by the flow of lava up a volcanic vent—it dips towards the E.S.E. at 80 degs. This rock has been described as filling the vent of a volcano, but Lamplugh points to the vertical columns as rather against this theory (may they not have been formed by weather cracks?); certainly, however, the ash becomes coarser

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as the stack is approached, as if a vent lay somewhere in that locality. The "Stack" occurs just at the S.W. salient of Castletown Bay.

Scarlet to Castletown.

At Scarlet Point we again enter upon bedded limestone, *Scarlet* being good Gaelic for *prominent bedded rock* (Fig. 7), so that the name has not been given to the igneous stack, but to the aqueous limestone. Between the stack and the bedded limestone we have rather a hard nut to crack. It is an irregular mass of metasomatised limestone, my first impression of it being that here we have got a small patch of the massive limestone faulted down opposite the lower bedded limestone. It contains a few weathered-out fossils, but no amount of hammering would ever enable one to obtain a sufficient series to settle its position in the geological scale. A figure and description of it will be found in the Sur. Mem., p. 246.

At Scarlet Point the bedded limestone occurs in several undulating folds (Fig. 8), and a peculiar feature in connection with them may be called "suture-jointing" (Fig. 9). This style of jointing occurs at and on each side of the crowns of folds or anticlines, and has evidently been caused by a gentle stretching of the bands of limestone when the strata were being folded by earth movements. It is also to be seen in other places. Where the bending of a limestone bed is pretty sharp abundance of short cracks traverse the crown of the bend in a longitudinal direction (Fig. 10), a fine example of this being exposed just now where the limestone is quarried on the shore between the Point of Scarlet and the Lime Kilns, the cracks being filled with calcite. Cumming's measurement of the bedded limestone of Scarlet is 129 feet, and estimate for total thickness 180 feet, which Lamplugh thinks is probably under the mark (Sur. Mem., p. 204).

From the Point of Scarlet to Castletown Harbour the limestone is all of the bedded type, but at the harbour the beds become more massive and assume steeper angles of dip. They contain the usual Lower Limestone fossils (very scarce here), and the great *Zaphrentis* reaches its maximum, as to

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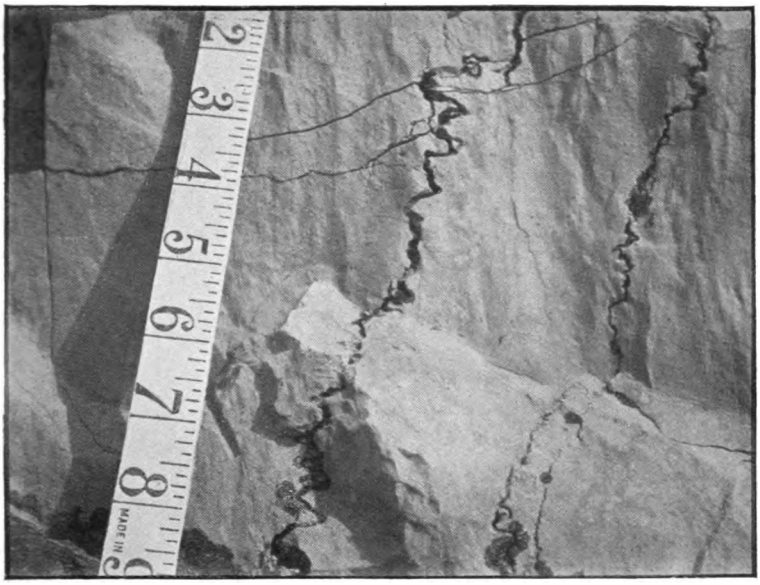

Fig. 9.—Suture-Jointing in Limestone, Scarlet Point.

Fig. 10.—Cracks in Limestone.

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numbers, on the shore opposite the office of the Scarlet Limestone Quarry, this bit looking like a regular "serpent rock." Here I measured a specimen 32 inches in length, and some of them reach a diameter of nearly 4 inches. The growth of this great coral has sometimes been quite gradual from base to calice; others swell out and contract again, as if the animal had languished for a time before it finally ceased to build. Specimens are occasionally seen quite semicircular in shape, and all are curved more or less. Some of the beds make an exceedingly durable building stone, easily chiselled, turn from dark grey to a lighter tint on exposure; and a fine example of its durable quality may be seen in the walls of Castle Rushen (Fig. 11).

At Knockrushen, an artificial mound S. of Castletown, an outcrop of impure-white limestone occurs, and was considered by Cumming to be a part of the Poolvash Limestone.

N.E. of Castletown Harbour bedded limestone continues, some of the bands being crowded with the débris of large crinoids.

The Silver Burn runs through Castletown Harbour between walls of limestone, having, as Lamplugh remarks, evidently left the line of its pre-glacial channel (Sur. Mem., p. 202). This gorge was probably cut out by a waterfall during the Peat period, when the land stood higher, the old pre-glacial valley of the Silver Burn being probably somewhere (underground) in the neighbourhood of King William's College.

Proceeding southward along the E. side of Castletown Bay we traverse the lower beds of the limestone series again till the base is reached. Generally speaking, there are few fossils, but some bands are crowded with them, and in the lower part, where the limestone becomes shaly, sandy, and pebbly, none are to be seen.

The lower bedded limestones are the only ones burned for lime in the island, but the lime burned from the boulders of the Northern Drift-plain, which probably came from Scotland, was considered by the farmers to be superior for putting on land to that made from the lower limestones in the south of the island (Berger, 1814). Berger also says that marl, stratified drift, massive drift, and material dug from ancient lakes was

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applied to light soils to the extent of 150 tons per acre, and cost £6 per acre, and that 90 bushels of burnt lime put on land in the south cost much the same. I was informed by a farmer that sea-weed is good for oats and turnips—not for barley—and a liberal spread of it will double the quantity of grass. It contains a lot of "lime" in the shape of *Spirorbis*, "corallines," &c.

The Basement Conglomerate.

Occasion was had to mention the Basement Conglomerate, before—at Port St. Mary—without having seen it, but now—at Langness Peninsula, west side—we have ample opportunities of studying it. It occurs as a massive bed resting on the upturned edges of the Manx Slates (Fig. 12), the latter having been much the same as we now see them in early Carboniferous times, and the time-gap between them and the Basement Conglomerate is immensely great. The Conglomerate is formed largely of quartz pebbles, with various igneous rocks and grits, and, although evidently derived from the rocks of the Slate series, there is very little slate in it, this softer material having been pounded up on an early Carboniferous sea beach into sand and mud, and carried off elsewhere. The conglomerate contains thin lenticular bands of red sandstone, and towards its upper part the pebbles become smaller and the passage into the overlying limestone gradual. There is no proof here that the conglomerate is part of the Carboniferous Formation, no Carboniferous fossils having been found—I examined it minutely several times and saw none—and, although it is like a patch of Old Red Sandstone, still, some of the Solway Carboniferous rocks are quite as red, and elsewhere Carboniferous fossils have been got in it.

Where exposed, the Basement Conglomerate is never seen to have been deformed by earth movements, and this has furnished an argument in favour of the pressure which deformed the Limestone and Volcanics as having come from rocks once higher up (Sur. Mem., p. 250). The weak point of the logic is that where these rocks are most deformed (Poolvash to Scarlet Stack) the Basement Conglomerate is not seen; however, Mr. Lamplugh's contention is probably correct.

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Fig. 11.—Castle Rushen, built of Limestone.

Fig. 12.—Basement Conglomerate on Manx Slate.

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Derby Haven to Cass ny Hawin.

Further examples of the Lower Limestones are to be seen along the shore in this traverse. Some of the beds being pretty dirty, show banding on weathered surfaces, the fossils being much the same as those already noted for this series; but one may be specially mentioned, and that is the reticulate coral, *Michelinia megastoma*, which is common at two or three places, and easily obtained from the shaly surfaces of limestone bands, the best being in the tideway opposite the Skilicore disturbance.

In the tideway at Ronaldsway there is a lot of crushed limestone, and limestone for burning was quarried here.

Bellerophons are common in certain parts, their shells being generally altered to "rock milk," but they have got such a firm grip of the rock that they will not crack out. *Cauda galli* sometimes covers as much as a square foot and a half of area, and *Chondrites gracilis* occurs. From an *M. megastoma* band I obtained two specimens of a new genus of sponge. (See Fig. 20.)

Some of the joints in the limestone on this shore are beautifully widened by weathering and tidal action (Fig. 13).

On the S. side of Cass ny Hawin (the burn foot) the limestone is truncated against the Manx slates by the boundary fault, which cannot be of any great throw, and is not again seen further north above ground. The fault has had the effect of altering the general dip and strike of the beds considerably. The Basal Conglomerate is seen near low tide, so that the strata here appear to be on much the same horizon as those of Port St. Mary.

Inland Lower Limestone.

The limestone in the three quarries near Crossroads may total 100 feet. In the north quarry the lowest part, so far, was worked first, in the mid one the middle part, and in the south one (the present working quarry) the highest part so far, so that this one may be carried much deeper. It exhibits very few fossils to the casual observer.

Between Crossroads and Ballasala there are other quarries, but the limestone does not differ from that near Crossroads. *Chonetes papilionacea* occurs here.

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These limestones belong to the lower bedded series, and are being worked for building and burning into lime.

Dolomitisation of the Lower Limestones.

As we have already seen, the Poolvash Limestone, in parts, on the Balladoole coast is intensely dolomitised. The Lower series has also partaken at certain places of this alteration, but it does not show so strongly as in the Upper series; however, there is great room for a thorough chemical investigation of this subject, as an eye-analysis is not always a correct one. Sometimes whole beds (so far as exposed) appear to be altered, and look as if the alteration had taken place coeval with the deposition of the limestone; but this is not likely, as the alteration is often seen to have proceeded from the sides of joints and fractures to greater or lesser distances laterally into the beds.

At what period the dolomitisation of the limestone took place is not apparent. Cumming thought that the dolerite dykes in the limestone had been the main agents in this alteration, but I think they have had nothing to do with it, and that Lamplugh was justified in rejecting this theory (Sur. Mem., p. 212). It is exceedingly strong in both the Lower and Upper series along the Balladoole fault, and is seen on the side of the Cass ny Hawin fault, and S. of it (Fig. 14) the massive dolomitised part here having probably been bedded at one time. It is frequent along the shore between Castletown and Scarlet quarries, but does not appear in either the Port St. Mary tideway section or in the inland quarries.

Where did the magnesia come from that altered the limestone to dolomite? From the Manx Slates? No. From the Volcanics? Not likely. From sea water percolating through cracks when the Carboniferous strata were being deformed by earth movements? Very likely. (*Note.*—As will be seen on p. 136, the Magnesian Limestone does not occur in the Manx strata.)

Deformation of the Limestone.

The earth movements to which the limestone in the S. of Man has been subjected may have been caused by the extension of strata on to the slate area to the N., even the limestone

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Fig. 13.—Joints Widened by Tidal Action and Weathering.

Fig. 14.—Bedded Limestone, Dolomitised.

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must have extended uphill a bit, as is proved by the fact that the remaining beds on the N. side of the area near the fault show no appearance of tapering away. During the Carboniferous period the Manx Hills were probably higher than now, and a deposit of strata up against their slopes would have a tendency to slip southward, and may have been quite sufficient to produce, by a sort of lateral pressure, all the ups and downs, boat synclines, and drumlin anticlines which have deformed the strata.

Knolls of Limestone.

It has been suggested that the knolls of impure-white limestone already mentioned as occurring along the shore (and inland) at Poolvash, near Balladoole House and S. of Castletown, are original structures formed on a sea bottom. I think this is exceedingly unlikely, and consider that they are just *roches moutonnées*, or glacial rock-drums, carved out of a thick bed of limestone into nearly their present shapes by ice, subsequent wave (on some of them), and sub-aerial action during the Raised Beach and Peat periods, and later having modified in a small degree their outlines. In an area so much deformed as this, parts of the limestone could not fail to be humped up as we have seen (p. 125), and other parts reduced to a state more easily denuded than the rest, and any one who tries his hammer on the knolls will find them to be pretty hard and sometimes much metasomatised.

However, it is a well-known fact that thickening of limestone beds does take place in short distances, and at Roscobie, in Fife (year 1907), the limestone being quarried there, in a short distance thickened to about double its ordinary thickness and got more massive, but by no means with such steep sides as the knolls of the Poolvash area, where no exposures showing an actual thickening of the massive limestone in short distances are to be seen, no quarries having ever been opened here in the impure-white limestone.

The Roscobie instance was clearly due to a spring of water probably furnishing a supply of lime utilised by the marine animals in building up the extra thick part, which was about 60 feet thick.

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In Cunningham Baidland Quarry, Dalry, Ayrshire, there was a drumlin anticline in the White Limestone, *not a thickening of the limestone*, but a clear case of the formation of a "knoll" by earth movements, there being a 60 fathom fault near its E. side and a larger one near the S. The Hurlet Limestone, which was not lifted, is still to be seen domed up.

Weather Cracks.

A peculiarity of some of the stacks of Poolvash Limestone in the tideway is that, although a bedding plain may dip at 30 degs., the weather cracks in the massive limestone above high water are practically perpendicular, a stack S. of the Goniatite Ridge showing this in an eminent degree.

Sub-aerial Weathering.

The sub-aerial weathering of the limestone along the shore and in stacks rising in the tideway is peculiar, and might be called Salt-spray Weathering (Fig. 15), the effect produced by it being an eminently rough structure of little peaks and ridges, and, as the inland stacks of rock in the fields do not show this structure, it has evidently owed its origin more to salt spray than to rain water. At the Ghaw Ghortagh some of the limestone shows this style of weathering to perfection.

Strata below Sea-level.

The borings in the N. part of the island show that strata of Triassic, Permian, and Carboniferous Limestone age occur, the latter crossing under the drift in a broad belt. No trace of the Coal Measures was obtained in the bores, but, as the Permian rocks lie unconformably on the limestone, great denudation evidently took place in pre-Permian times, which may have removed the Coal Measures.

The Trias contains a lot of Salt Beds aggregating 75 feet in thickness, and some of the marls have a considerable percentage of salt.

The Magnesian Limestone—which in Cumberland is only 10 feet thick—is absent in the bores (Sur. Mem., p. 578).

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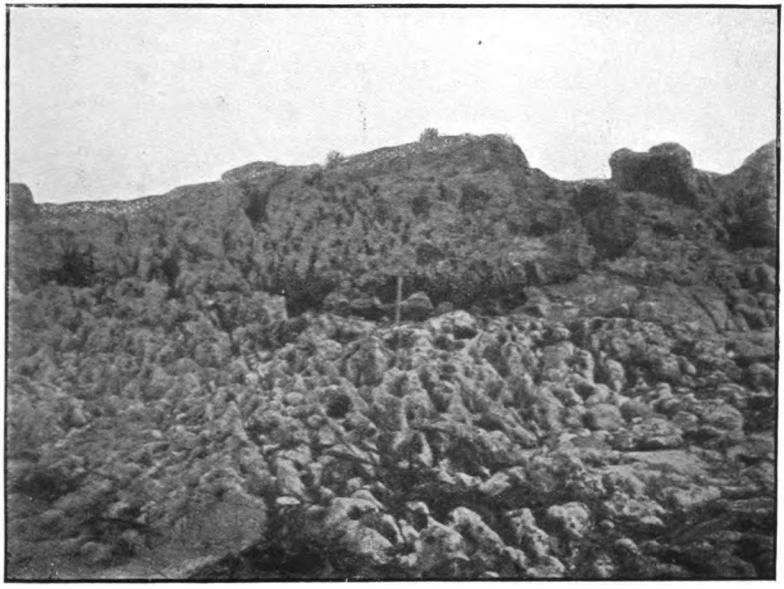

Fig. 15.—Salt-spray Weathering of Limestone.

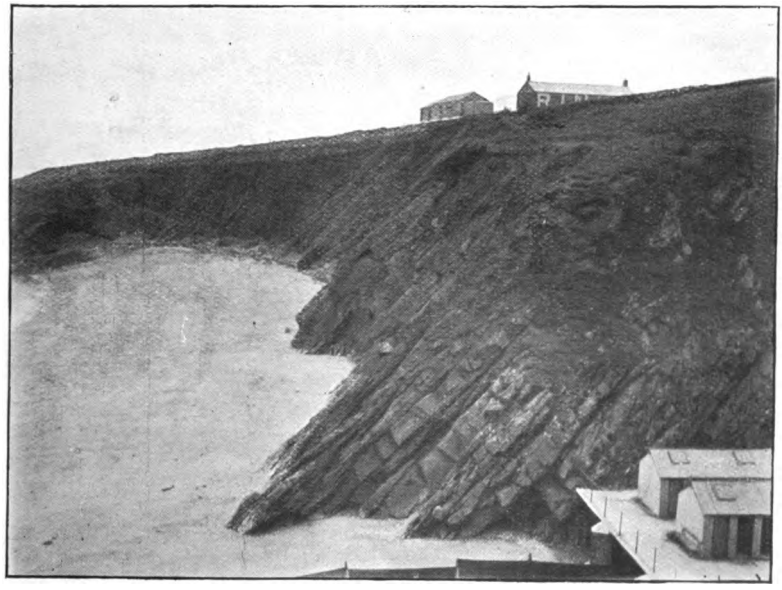

Fig. 16.—Peel Sandstone.

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Dykes in the Limestone.

Dykes are common in the Manx Carboniferous Limestone, quite as numerous as they are in any place in Arran. They appear to be all of Tertiary age, belonging to the N.W. series, and are of a soft, greenish olivine dolerite, more easily abraded than the limestone, and so along the shore they are to be looked for in the bottoms of ghaws (gutters). They are generally too soft to be used as road metal, and are quite different from the hard anamesite N.W. dykes in the W. of Scotland.

Cumming (as already stated) thought they had been powerful agents in the dolomitisation of the limestone, but their effect has been exceedingly feeble, and they are long posterior in age to the dolomitisation. About all they have done is to marmorise the limestone for a few inches on each side—sometimes not even that. The greatest effect produced by any dyke is to be seen in the black marble quarry of Poolvash, where the stratification has been destroyed for 2 to 3 yards from the sides of the dyke cutting the strata here.

Drift, Raised Beach, and Peat Periods.

As the limestone has been modified to a certain extent during the above periods; it will be necessary to make a few remarks on them.

In the north of the island the drift is immensely thick, 250 feet in the sea cliffs, to which has to be added 400 feet ascertained by bores. The sea cliffs exhibit magnificent sections of drift composed of mud beds, laminated clay, sand, and gravel; boulders are remarkably few, but some large ones occur, the *tout ensemble* being a magnificent display of stratification, with (on the W. coast) an average dip at an average angle of about 20 degs. to the S.W. The stones have come from Man, England, Ireland, and Scotland, and in the northern plain Scottish boulders are so numerous as to have been long used in building and road mending.

At a part of the N.W. coast, where the cliff was 78 feet high, I saw a Loch Garabal granite boulder half-way up, 5 feet by 3 feet 6 inches in size. Ailsa rock is quite common,

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and I noted a Mulwharchar granite block from the centre of the Forest of Starr, the ordinary Galloway granite being frequently seen.

Mr. Lamplugh supports the theory that the fossils in the drift were mostly hauled out of the bottom of the Irish Sea by glacier ice (Sur. Mem., p. 337), but to this I cannot subscribe, nor does the dip of the beds admit of it.

On South Barrule granite blocks occur several hundred feet higher than the source from which they were derived, viz., the Foxdale area; and, as the recorded blocks of that granite are all S. or S.W. of that area, this is thought to be in favour of a land-ice theory, but, as the great bulk of the ice evidently came from the N., floating ice would prevent blocks from being carried north.

The Manx drift contains a large quantity of shelly débris, doubtless mostly produced by ice occasionally grating on the sea bottom; but it has also got abundance of shells which have not received a single scratch. Many of the beds are twisted and deformed, but this can easily be explained by floating ice occasionally ploughing into them.

Had glacier ice grated against the north end of the island, then we ought to have a hollow there (instead of deposits), as there is in front of a boulder in a river. On the other hand, floating ice in its progress south would be so far hindered by coming in contact with the land, and get time to melt and deposit so much of its débris in stratified courses, and it is a well-known fact that pressure melts ice; so to these two agencies —hindrance of motion resulting in pressure—we doubtless owe the great accumulation of drift at the north end of the island.

In the south of the island there is exceedingly little drift. At Port St. Mary the limestone has been much crushed in its upper beds (probably by ice), and cemented by stalagmite. Here I detected two sets of glacial striæ on the surface of the limestone, the one crossing the other at nearly right angles. The Survey Map shows only one set of striæ here.

This bears out my contention that after the great land-ice scrape the land sank and the ice lifted and floated before deposition of sand, clay, and boulders began (*Trans.* Supl. to Vol. xi.).

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A Raised Beach in Man occurs 10 to 12 feet above tide, but has been higher, as will be seen. It sometimes appears as solid rock, and the boulder clay under it has at parts been dug out into caves. Patches of solidified gravel in Drift and Beach beds are called Scrablags by the natives.

A Peat bed is of great interest, as showing both an elevation and depression of the land. It has been long known at the N.E. corner of Carrickey Bay, where it has furnished some antiquities, human remains, and remnants of dwellings, and trees are common in it. I dug down 18 inches into it at half-tide, but did not reach the base. It has been traced to low water. I detected it in a new locality at the mouth of the Cass ny Hawin, between tides, where 6 yards of it was laid bare by the stream.

How far the land was elevated during the Peat period cannot be known, but this episode steps in to help us in explaining certain features of the tideway not otherwise easily accounted for, and these are hollows, as at Ghaw Ghortagh and other places, and the limestone gorge at Castletown Harbour.

A salt-water spring gushes out of the limestone in the tideway N. of Ghaw Ghortagh, and Cumming suggested that the water entered and flowed out of an underground cavern.

Near Balladoole old smithy I saw gas, or air, bubbling up strongly through the water all the time the tide was in, and when it went out no water flowed from the orifice, the water which had displaced the air (if it was air) having evidently got away at a lower level.

A short distance W. of Burrow Head, in Wigtownshire, I discovered, on 29th June, 1904, the mouth of a cave 10 feet high, chokeful of solid stalagmite. As the tide sometimes reaches on to the bottom part of the stalagmite, it could not have been deposited in the cave with the land standing at its present level, and was very likely deposited when the land stood higher during the Peat period. As nothing is definitely known of the Peat period in Scotland, this would be an exceedingly interesting cave for a geologico-archæologist to clean out and explore. As showing the complicated nature of the ups and downs of the earth's crust during recent geological times, I may say that the stalagmite is bored by the burrows

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of sea animals at a point where the water does not now reach it. This stalagmite-filled cave is on a very rocky part of the coast not far W. of the outer ditch of Burrow Head Fort.

Diseased Fossils.

Plate XVI.

Disease appears to have run in certain species of Carboniferous animals more than in others; and of the different orders, the brachiopods (probably from their sedentary habits) were by far the most afflicted, *Productus* and *Orthis* having suffered more than others, perhaps from hereditary complaints of the internal organs, resulting in a *pinching* of the valves at certain parts. On a number of the more prominently marked specimens I laid aside for examination from the Isle of Man Carboniferous strata, the following twenty-seven species are strongly scarred by disease:—

	Specimens.
Orthis resupinata,	14
Productus martini and concinna,	11
,, *punctatus*,	3
,, *cora*,	2
,, *semireticulatus*,	1
,, *fimbriatus*,	1
,, *striatus*,	1
,, *scabriculus*,	1
Strophomena rhomboidalis, var. distorta,	1
Spirifera glabra,	6
,, *lineata*,	2
,, *striata*,	1
Orthotetid,	1
Athyris ambigua,	1
Terebratula hastata,	2
Leiopteria laminosa,	2
,, *lunulate*,	1
Posidonella pyriformis,	1
Grammatodon obtusus,	3
,, *squamifer*,	1
,, *theciformis*,	2
Mytillimorpha rhombea,	2
Edmondia senilis,	1
Cypricardella parallela,	1
Sanguinolites striato lamellosus,	1
Stems of *Crinoids*, a few.	

Note.—A mechanical injury to a fossil is quite easily distinguished from an *awr* caused by a disease of some internal organ.

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Palæontology.

Cumming has given a list of 222 species of fossils from the Manx Carboniferous rocks. The Government Survey list, published in 1903, numbers 237 species and varieties.

During the ten weeks I hammered at the Manx Carboniferous rocks I added 377 species and varieties to the Government list, including 2 genera and 30 species new to science, and with additions made by Dr. Hind (Pro. York Geol. Soc., vol. xvi.) and our members, Messrs. Dunlop and Wright, the list in species and varieties now totals 634.

I am deeply indebted to the following palæontologists for assistance in naming the Manx Carboniferous fossils:—Mrs. J. Longstaff, Dr. George Jennings Hinde, Dr. Wheelton Hind, Dr. Robert Kidston, Dr. Bather, Dr. Ivor Thomas, Dr. G. W. Lee, and Messrs. Macconochie and Carruthers, and to Mr. R. Dunlop for the bulk of the photographs.

In the lower bedded strata the principal feature is the corals; there are not many of them (33 species), but conspicuous from their size, *Michelinia megastoma*, indicating rather a low horizon, I found two specimens of it in the Arbigland beds of the Solway, but none have been got in higher strata in Scotland.

Goniatites are exceedingly rare—only two species, including the large *G. henslowi*.

Palæontologists have been perplexed with the *mixture* of the species in the Poolvash Limestone, some going the length of thinking that certain kinds of them have been drifted into this favoured spot, but as a worn specimen is not often seen out of the conglomerate beds I believe they are mostly all *in place*, and can be accounted for by limey mud being quietly drifted into the area and sealing them up before they had time to decay on the sea bottom. For many years I kept my eye on the Hurlet Limestone worked in Ayrshire, and found fossils to be exceedingly scarce in it, the conclusion I came to being that deposition had been so slow that the shells decayed on the sea floor long before they could be covered up.

Plants are frequent in the black bands in the impure-white limestone at Ghaw Ghortagh, occasionally in the Posidonian Schist, and Dr. Kidston says of them that they present a decidedly Calciferous aspect—there are no fresh water shells associated with them, all the fossils got here being marine.

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Sponges and Foraminifera are very scarce. On certain horizons in the lower part of the impure-white limestone the smaller Entomostraca are abundant, and in the upper part (under the interbedded black series) the larger ones are quite common—in all 65 species. Some of the large Entomostraca always rot to a rusty colour, as if the animals had had the power of extracting iron salts from the sea water. Trilobites are occasionally got—10 species.

Corals are rare as individuals, only 3 or 4 species turning up in a day's hammering from 9 a.m. till 5 p.m., but the number of species is astonishing (33), and the assemblage perplexing. Thirty-six species of Isle of Man corals have been got in the Lower Limestone series of Scotland, only 5 in the Upper.

Polyzoa are scarce—8 species in the Manx Lower Limestone, 10 in the Upper.

Brachiopods are exceedingly abundant—*Spirifers*, *Martinia*, and *Spiriferina* (35 species and varieties), *Productus* (50 species and varieties), being the commonest genera. *Productus* spines, which are conspicuous in the Scottish strata, are not so in the Manx.

Orthis attains a large size and ponderous weight; *Spirifers* are sometimes large, and often contain the spiral arms.

Sixty-two species and varieties of Manx brachiopods have been got in the Lower Limestone series of Scotland, 40 in the Upper.

Bivalves are abundant in the Poolvash Limestone from the Ghaw Ghortagh to Poyll Ritchie, although at parts they are scarce—122 species in the Manx Upper beds, only 4 in the Lower.

Posidonomya becheri is considered to be a good zonal fossil, occurring above the Yorkshire "Massif" in England. It is never seen in the impure-white limestone, but always in the black beds, both in the bands enclosed in the limestone and in the Posidonian Schist above it. This zone must have taken up a considerable amount of time—the shells came into the district in a vigorous state, and if they had an opportunity of leaving it seem to have done so in much the same condition, so that this zone must be of much greater vertical extent than it is represented in Man. Mr. Carruthers has recently informed us that it occurs in the Calciferous strata of Calder

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Glen, East Kilbride; but it has never been got in the Solway Beds nor in the Lower Limestone series in Scotland.

Fifty-nine species of Isle of Man bivalves occur in the western Scottish Lower Limestone series, and 40 in the Upper.

Neither *Nuculas* nor *Ledas* were seen in the Manx Limestones. It is remarkable that in the Poolvash Limestone, where bivalves are so common, a specimen with the valves united is not often got. Cephalopods are also abundant, and it has occurred to me that they fed on the bivalves, which they could easily suffocate by twisting their arms round them, and then scraping out the animals. This would account for so many single valves occurring here.

Gasteropods are fairly well represented—70 species from the Upper series, only 1 from the Lower, some of them pretty large, 17 being got in the Lower Limestone series of Scotland and 14 in the Upper.

Heteropods, 9 species in the Upper Limestone, those in the Lower not being determinable.

One of the charms of the Poolvash Limestone is the number of Goniatites to be obtained (10 species), some of them having colour markings. It is a long jump and a high "speel" to Gair, near Carluke, in the Upper Limestone series of Scotland, but the same number of species (10), though few in individuals, have been got there, and it might be worth while for the members of this Society to open up the old shale heaps, which contain a lot of fossils, some of them not readily got elsewhere. In the Lower Limestones of Ayrshire, and the still lower strata of the Solway, Goniatites are rare.

Ten species of Cephalopods have been got in the Lower Manx Limestones, 59 in the Upper, 16 of these having been got in the Lower Limestone series of the West of Scotland, 16 in the Upper.

Fish remains are exceedingly rare, the few species got being represented by single specimens. How is this to be accounted for? They cannot have rotted away, as phosphate of lime fossils are much more durable than carbonate of lime ones are, and the Armagh Limestone, where fish remains are so common, is much of the same quality as that of Poolvash.

A number of samples of the softened limestone which I washed for microzoa seemed ideal material in which to get Conodonts, but none turned up.

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Traces of silica are sometimes seen in occasional specimens, some of the Lower Limestone corals being hard to cut, but no really silicified fossils were observed.

Chert occurs occasionally in the Lower Limestone series, the Posidonian Schist, and the Volcanics, but none was seen in the Poolvash Limestones.

The following Isle of Man fossils extend into the Marine Band in the Lower Coal Measures of Scotland (13 species):—

Chonetes buchiana.
Chonetes hardrensis.
Orbicula nitida.
Productus semireticulatus.
Productus scabriculus.
Productus margaritaceus.
Athyris ambigua.
Murchisonia striatula.
Euphemus urei.
Protoschizodus axiniformis.
Conularia quadrisulcata.
Pterinopecten papyraceus.
Glyphioceras micronotum.

ABSTRACT OF MANX CARBONIFEROUS FOSSILS.

	New Genera.	New Species.	Species and Vars.
Algæ,	—	—	3
Plantæ,	—	—	13
Spongidæ,	1	2	4
Foraminifera,	—	—	17
Actinozoa,	—	4	64
Annelida,	—	1	5
Echinodermata,	—	—	14
Crustacea,	—	—	75
Polyzoa,	—	1	18
Brachiopoda,	—	8	142
Lamellibranchiata,	1	4	124
Gasteropoda,	—	7	72
Heteropoda,	—	—	9
Pteropoda,	—	—	1
Cephalopoda,	—	3	65
Pisces,	—	—	7
	2	30	633

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Conclusion.

The Manx Bedded Limestones appear to be on a pretty low horizon in the Carboniferous formation. The presence in them of *Michelinia megastoma* and *Syringopora* indicate this, and, although *Syringopora* is common on the Solway—where the limestones are also thin bedded—*M. megastoma* is exceedingly rare there. *Syringopora* is very rare in the Lower Limestone series of Scotland, and *M. megastoma* has never been found in that series.

In the upper massive limestone of Poolvash there is a thin black series of beds with abundance of *Posidonomya becheri*, which also occurs frequently above that limestone. This "index shell" points to a zone of strata occurring in the beds above the Yorkshire "Massif," but probably lived elsewhere before the Yorkshire "Massif" was finally deposited. It has never been got in the Lower Limestone series of Scotland.

It might be looked for in a thin band of black shale at the N. end of the Thirlstone Sandstone, Arbigland, on the Solway.

All the Palæontological evidence is in favour of the highest Manx Limestones being on a lower horizon than the Hurlet Limestone series of Scotland.

The Volcanic rocks of the S. of Man may be of the same age as that of the great Volcanic outbreak, so well represented in the Dalry, Kilbirnie, Campsie, Kilsyth, &c., Hills.

There are few places in the British Islands where such an interesting series of rocks occur, and where a geologist can spend a few more profitable days than at the south end of Eilean Mona.

Peel Sandstone.

Personally I can say little about the Peel Sandstone, not having obtained a single fossil from it. Much discussion as to its age has taken place; the balance of evidence is in favour of its being of Lower Carboniferous age, although Permian has been suggested. It certainly looks like some of the Calciferous Sandstone of the West of Scotland, and its steep dip furnishes a strong argument against its being of Permian age (Fig. 16).

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Manx Slates.

It forms no part of this paper to deal with the Manx Slates, but, as they form the foundation for the Carboniferous beds, and have had some influence on them, a few notes culled from the Survey Memoir may be given. Their age is problematical—probably Cambrian—fossils few, a doubtful graptolite or two, some "worm" casts and tracks, and a doubtful trilobite. They have been correlated with the Skiddaw Slates, but Lamplugh thinks there is no relationship. Horne says they cannot be compared to the Palæozoics of the South of Scotland—may be on a lower level—and I can confirm this opinion. They contain no conglomerates (no shore conditions), the coarsest beds being grits, often severely squeezed, shorn, slicken-sided and cleaved, strike S.W. to N.E., dips various, apparent thickness immense, actual thickness probably a little more or less than 2000 feet, reach an altitude of 2034 feet.

Shear-cleavage sometimes passes through the slates in three directions (Fig. 28, Sur. Mem., p. 83). They are traversed by igneous rocks, which are folded up with them; by dykes, which are not folded with them; and by elvans. Two masses, of muscovite-granite, and of a granitite surrounded by basic rock, occur in them, and they are traversed by numerous quartz veins of various ages.

In the caves at Cass ny Hawin there are dark seams in the slates which one thinks he has nothing to do but split up and get graptolites in, but when laid open the surfaces are seen to be intensely slicken-sided. If it were possible to obtain bits of these bands which had escaped crushing, fossils might be got from them. Here some dykes may be seen twisted up with the slates, but quartz veins cut both slates and dykes (Fig. 17).

It was the opinion of the older geologists that the Manx Slates formed a great anticline, with an N.E. and S.W. axis, and that the beds next the coasts were the most recent, but Surveyor Lamplugh thinks that they form a "compound synclinorium," and that the beds next the E. and W. coast are the oldest.

The Manx Slates make poor building stone, but in the old quarries of Spanish Head and the hillslope between Ballaugh and Gob y Volley, beam-like masses of slate of the laminated

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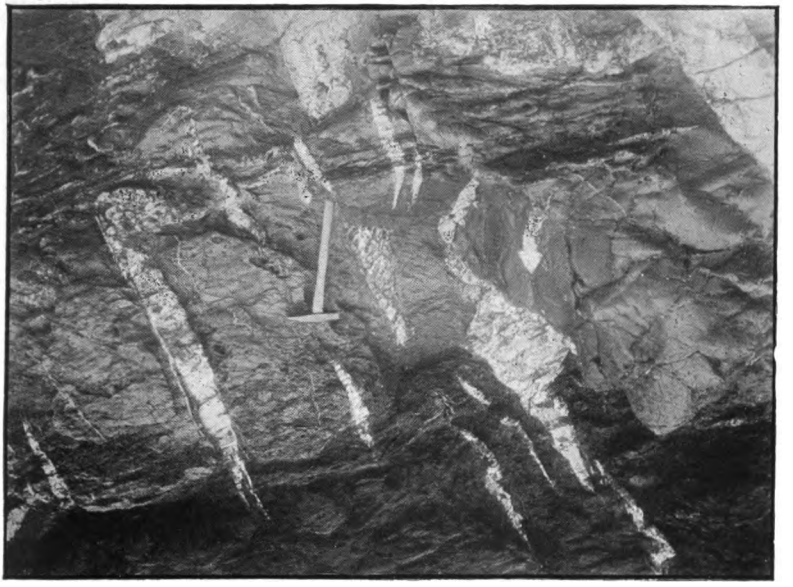

Fig. 17.—Quartz Veins in Slate, Cass ny Hawin.

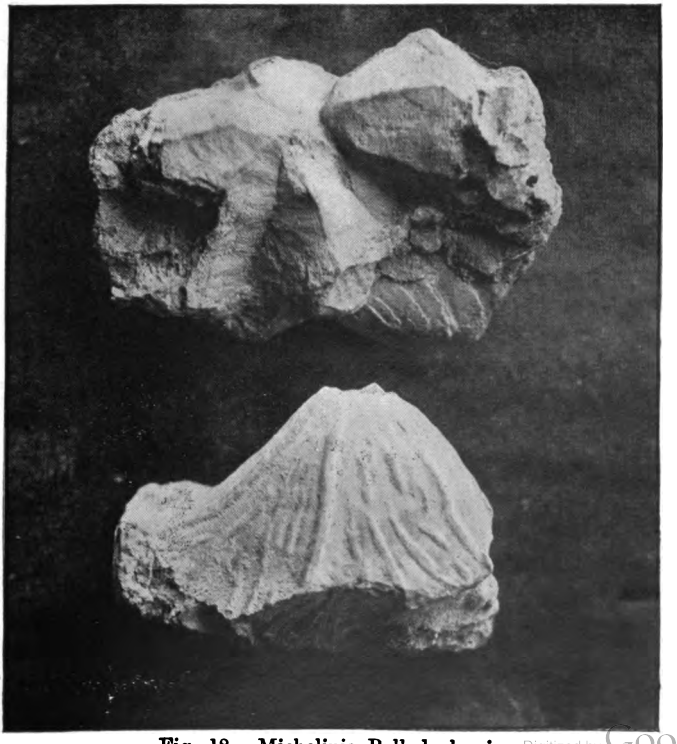

Fig. 18.—Michelinia Balladoolensis.

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argillaceous type, up to 24 feet in length, have been quarried, and Lamplugh thinks they obtained their peculiarly tough and enduring qualities from being compressed in the troughs of folds. Macculloch says of them—A beam 15 or 16 feet long was bent 5 inches before it broke. These slate-beams are often seen forming "planks" over streams, as posts, lintels, combined roofing and flooring for rooms, as in Castle Rushen, and at the corners of many fields there are steps, generally of limestone, at the head of which there is often a cross-beam of slate, this arrangement forming a very convenient "stile."

Mineral Veins.

The Manx Slates are traversed by many mineral veins, but only two have held out profitably to our time, the Foxdale vein, an E. and W. one, and the Laxey vein, a nearly N. and S. one. Eighty-three minerals have been recorded from the veins.

The great vein, 40 feet wide, at Stack Mooar, 2 miles S.E. of Ramsey, which has yielded hematite, might if followed downwards turn out a galena vein, that mineral generally replacing hematite at lower depths, similar remarks applying to the great Brada Head vein.

Drainage System.

Lamplugh regards the drainage system as all insular, but after a run through the low, central valley I was strongly inclined to think that it had principally been cut out by a larger river than could possibly exist in such a small island.

Although insular, the drainage was initiated at a time when the slate had been covered by other strata, and this forms the strongest support to the theory that the deformation of the limestones in the S. was caused by a great weight of strata slipping a little on the southern slope of the Manx Hills (see p. 135).

The streams have not been guided by the direction of the strike of the slates, and Lamplugh only gives two instances where streams have followed natural features for short distances, viz., Sulby Glen, which runs for a bit along some crush-conglomerate, and Glen Agneash, which coincides for a short distance with the outcrop of the Laxey Lode.

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One of our old librarians, the late James White, considered the central valley as having been blocked out by two streams running in opposite directions pretty near each other, and having their head waters overlapping to a considerable extent (*Trans.*, vol. 7, p. 84), and Lamplugh has also come to a similar conclusion.

Irish Elk.

No Post-Glacial Connection with Britain.

Kendall, after a study of the flora and fauna, considered that there had been no post-Glacial connection with Britain, and thinks the Irish elk reached Man over a glacier or frozen sea. I may say his finding was that Man is exceedingly poor both in plants and animals.

Michelinia Balladoolensis, Sp. Nov.

Corallites in close radiating clusters, which easily separate. In some of the clusters the apices are directly opposite one another, and hollow where weathered. Individual corallites, limpet-shaped, compressed (in some), with five to six angles; largest one seen, 1½ inches wide by 1 inch high. Corallites, with a few interior, irregular ridges (or septa). Two or three layers of minute oval dissepiments, or cells, level up the spaces between the strong projecting (where weathered, as seen in Fig. 18) ribs, so that the cells may have formed an epitheca. Interior filled with limestone or calcite.

Locality.—In the soft, altered limestone near the old smithy, Balladoole. The first specimen, a single corallite, was got by Mr. Wright, and we called it the Carb-limpet.

Æchmina Carbonifera, Sp. Nov.

This species resembles very closely Professor T. R. Jones's *Æ. bovina* from Wenlock shale (A. and M. Nat. His., June, 1887, Plate XIII.), the principal difference being that the spikes swell out at the base where attached to the shell, but do not touch the edge of the shell. Size, length fully 1-16th of an inch; width over spikes, the same (Fig. 19).

Locality.—In the decomposed limestone, old smithy, Balladoole.

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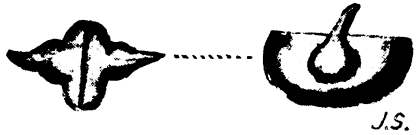

Fig. 19.—Æchmina Carbonifera.

Fig. 20.—Mona Monensis.

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Mona Monensis, Gen. et Sp. Nov.

A mesh of slightly curving tubes sending off branches, often a number of them at special parts forming knobs at the points they spring from. Tubes generally smooth, but sometimes having small pustules, which may be abortive branches. The general appearance will be seen from the photo., which is of the natural size (Fig. 20).

This sponge forms a thin cake on top of a specimen of *Michelinia megastoma*. It is not siliceous, but is harder than the limestone which has been dissolved (naturally) from about it, and into which the branches are seen to dip at various angles.

Locality.—Shore S. of Cas ny Hawin.

Table Showing the Vertical Range of the Isle of Man Carboniferous Fossils in the South and West of Scotland.

c = common. *f* = frequent. *s* = scarce. *r* = rare.
s = from Survey list. *h* = from Dr. Hinde's list. *c* = from Cumming's list.

Names of Fossils.	Isle of Man.		Sol-way.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Plantæ.					
Land plants—					
Poacites pitcarni,		f			
cf. *Telangium bifidum*,		f			
,, *affine*,		f			
Rhodea, sp.,		s			
Adiantites antiquus,		f			
(s) ,, *machaneki*,		+			
Spiropteris, sp.,		s			
(s) *Sphenopteris pachyrachis*,		+			
,, p. var. *stenophylla*,		+			
(s) ,, *sub-geniculata*,		+			
(s) ,, *aff. bifida*,		+			
(c) *Lepidostrobus ornatus*,		+			
(c) *Calamites*,		+			
Seaweeds—					
Spirophyton candagalli,	c			c	c
Chondrites gracilior,	f		c		
Laminiaria (?),	c		c		
Cumming's locality for plants was rediscovered by the collector, Mr. D. Tait.					

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Names of Fossils.	Isle of Man.		Sol-way.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Spongidæ.					
Hyalostelia smithi,		r		c	r
Clionida arbiglandensis,	f	r	f		
Pulvilus, sp. nov.,	s		s		
Mona monensis New Genus,*	r				
Foraminifera.					
Stacheia congesta,		s		c	f
Endothyra macella,	r			s	
,, *crassa*,	r			s	r
,, *bowmani*,	s			c	c
Valvulina palaetrochus,	r			c	c
,, *conica*,	r				
Lagena parkeriana,		f			r
Orbiculina, sp.,		r		r	
Archæodiscus kerreri,		r		r	r
Climachamina antiqua,		r		f	
Pulvinalina broeckiana,		s		r	
Trochammina incerta,		f		c	c
Textularia multilocularis,		f			
Globigerina, sp.,		r		s	
Nodosinella priscilla,		r			
Saccammina corteri,		r		r	
Fusulina (?) (always crystallized), in black beds, (several undetermined).		c			
Actinozoa.					
Fistulipora incrustans,		r		s	r
,, *minor*,		r		s	
Monticulipora (Chætetes) tumida,	c		c		
Favosites parasitica,		s		c	
,, cf. ,,		r			
Syringopora gigantea,	r		r	r	
,, *distans*,	r				
,, *geniculata*,	f		f		
,, *ramulosa*,	f		c	r	
Aulopora complanata,		r	r	r	
Amplexus coralloides,		c		s	
Zaphrentis bowerbanki,		r		r	
,, *amphitheca*,		r		r	
,, *griffithi*,		r			

* Dr. G. J. Hinde says of the specimens—"Their structure so far differs from any sponge known to me, fossil or recent. . . . On the other hand, there is no apparent relationship to any other group." See Fig. 20.

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Names of Fossils.	Isle of Man.		Solway.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Actinozoa—*continued.*					
Zaphrentis curvilinea,		r		s	
,, *aff. costata*,		r			
,, *patula*,		r		r	r
,, *intermedia*,		r		r	
,, *omalinsi*,		r			
,, *koninzki*,		r		r	
,, *cyathina*,	r		r		
,, *eniskilleni*,	f	f		f	
Lithostrotion portlocki,		s	c	r	
(s) ,, *basaltiforme*,		+	c	r	
,, *(Lithodendron)*,					
,, ,, *phillipsi*,	f		f	r	
,, ,, *cyathophylloidea*,	r	r			
,, ,, *fasciculatum*,	r		f	f	
,, ,, *martini*,	f		f	r	
,, ,, *affine*,	f		s	r	
,, ,, *irregulare*,	s		c	c	
Campophyllum murchisoni,	s			r	
,, *(Zaphrentis) cylindricum*,	c		f	f	
Lonsdalia floriformis,		r		r	r
,, sp. nov.,		r			
Centrophyllum cylindricum,	r				
Aulophyllum haimeanum,	r			r	
,, *wunchianum*,	r			r	
,, *cylindricum*,	r				
Aspidophyllum, cf. *elegans*,		r			
Dibunophyllum muirheadi,		s		r	
,, *subibicina*,		r			
,, *macchesnyi*,		r		r	
,, *turbinatum*,		r			
Michelinia tenuisepta,		r	r	s	
,, *favosa*,	r		r	r	
,, *megastoma*,	c		r		
,, *balladoolensis*, sp. nov.,		s			
Densyphyllum charlestonensis,		r		r	
Carcinophyllum, sp.,		r			
Lophophyllum tortuosum,	s				
,, *reteforme*,	r				
Caninia, aff. subibicina,	s				
Clisiophyllum, sp. nov.,		s			
(s) *Cyclophyllum fungites*,	+			r	r
,, *aff. wunchianum*,	r				
(s) *Dania*, sp.,	+				
(h) *Amplexiphrentis*, sp.,	+				
(h) *Cyathaxonia costata*,	+				

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Names of Fossils.	Isle of Man.		Sol-way.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Actinozoa—*continued.*					
Cyathophyllum regium,		r		r	
(h) ,, *murchisoni*,	+				
(h) *Koninckophyllum*, sp. nov.,	+				
Heterophyllia mirabilis,		r		c	
Chætetes tumidus,	f		c	c	f
Palæcis cyclostoma,	r			f	
Annelida.					
Spirorbis helicteris,		r		r	
Ortonia, sp. nov.,	r				
Serpula carbonarius,	r	r		f	
Vermilia minuta,		s		s	s
(Twisting burrows) (in black beds),		c			c
Echinodermata.					
Platycrinus gigas,		r			
,,		r			
Poteriocrinus crassus,	c	c	c	c	c
,, near *plicatus*,		r			
Rhodocrinus, near *uniarticulatus*,		r		r	
Megistocrinus, sp.,		r			
Delocrinus, sp.,		r			
Scaphiocrinus, sp.,		r			
Dorycrinus, sp.,		r			
Scytholecrinus, sp.,	r				
Parisocrinus, sp.,	r				
Archæocidaris urei,	f		c	c	c
,, *munsteriana*,		r		r	
(h) *Palæchinus*, sp.,	+				
Crustacea. (Entomostraca.)					
Cyclus simulans,		r			
,, *radialis*,		r			
Brachycinetus rankiniana,		r			
Rhombinea belgica,		c			
Sulcuna lepus,		r			
,, *cuniculus*,		r			
Cypridina youngiana,		s		r	
,, *primæva*,		r		s	
,, *grossartiana*,		r		r	
,, *brevimentum*,		r		r	

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Names of Fossils.	Isle of Man.		Sol-way.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Crustacea—*continued.*					
Cypridina hunteriana,		c		r	
,, *pruniformis*,		r			
,, *scoriacea*,		s			
,, *phillipsiana*,		c		s	
Cypridellina elongata,		r			
,, *barrovi*,		s		s	
,, *intermedia*,		r		s	
Cypridinella superciliosa,		r		s	
,, *clausa*,		r			
,, *cummingi*,		r		s	
,, *vomer*,		r		s	
Cypridella cyprelloides,		r			
,, *koninckiana*,		s		s	
Offa arrandiana,		r			
Polycope youngiana,		s		r	
,, *simplex*,		c		r	
,, *barrovi*,		r			
Entomachonchus globosus,		s		r	
(s) ,, *orbicularis*,		+			
,, *scouleri*,		s		r	
Philomedes bairdiana,		r			
(s) *Cyprella chrysalidea*,		+		s	
Kirkbya costata,	r			r	
Cytherella murchisonia,		f			
,, *inflata*,		s		r	
,, *valida*,	s				
,, *benniei*,		s			r
,, *atlantosaurica*,		r			
Cythera siliqua,	f				
,, *obtusa*,		f			
,, *bailyana*,		s			
,, *wightiana*,		s			
Bairdia genitziana,	s				
,, *hisingeri* v. *elongata*,		f			
,, *siliquoides*,		s		r	
,, *subelongata*,	f	f		f	
,, *griffithiana*,		s			
,, *murchisonia*,		f			
,, *elongata*,		f			
,, *nitida*,		f			
,, *æqualis*,		s			
Candona subovata,	f				
Moorea obtusa,	r				
Æchmina carbonifera, sp. nov.,		r			
Argillœcia æqualis (got in Calciferous),		r			

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Names of Fossils.	Isle of Man.		Sol-way.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Crustacea—*continued.*					
Leperditia parallela,		f			
,, *hinksi*,		f			
Bithocypris pyrula,		f		r	
,, *thraso*,		s			
,, *symmetrica*,		f			
,, *concinna*		f			
Macrocypris carbonica,		s		s	
,, *pusilla*,		s			
Metacypris coneformis,		s			
(Trilobita.)					
Pontocypris mawii,		s			
Griffithides globiceps,		s		r	
,, *longiceps*,		s			
,, sp.,		r			
Phillipsia gemulifera,		f			
,, *derbiensis*,		s			
,, *colei*,		s			
,, *truncatula*,		s			
,, *seminifer*,		f			
,, *laticaudata*,		r			
(h) ,, *poleni*,	+	+			
Polyzoa.					
Fenestella membranacea,		f		f	f
,, *polyporata*,		f			
,, *tenuifila*,		s	r	c	
,, *pleibeia*,		f	c	c	c
,, *formosa*,		s			
,, *carinata*,	s			s	
,, *nodulosa*,		s		r	
(s) ,, *porata*,		s			
Stenopora, sp. nov.,*		r			
(Multilaminar stenopore),		r			
Bartostonella, sp.,	r				
Rhombopora, sp.,	s				
Tabulipora, sp.,	r				
Sulcoretepora robertsoni,	f		f	c	
Diastopora megastoma,	f		f	c	f
Ceriopora similis,	r		r	c	c
Rhabdomeson gracile,	c		f	c	s
Glauconome grandis,		f			r
Polypora laxa,		r			

* Will be described by Dr. Lee.

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Names of Fossils.	Isle of Man.		Solway.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Brachiopoda.					
Spirifera, cf. *subcinctus*,		s			
,, *striata*,		f			
,, *duplicicosta*,		f		c	
(s) ,, *convoluta*,		+			
,, cf. *grandicostatus*,		r			
,, *planata*,		+			
,, *bisulcatus*,		f		c	c
,, *triangularis*,		s		r	
,, *tornacensis*,		s			
,, *trigonalis* (varieties),		f	r	c	c
,, *mosquensis*,		s	r		
,, *pinguis*,		r	r		r
,, *integricostata*,		c			
,, *lingulifera*,		r			
,, *rhomboidea*,		s			
,, *decora*,		r			
,, *stringocephalus*,		r			
,, *acuta*,		s			
,, *princeps*,		s			
,, *subconica*,		r			
Martinia ovalis,		f		f	
,, cf. *ovalis*,		r			
,, *glabra*,		c	c	f	r
,, *glabra*, v. *oblata*,		r			
,, cf ,,		f			
,, *carlukensis*,		r		r	
,, *glabra*, v. *decora*,		c			
,, ,, ,, *symmetrica*,		r			
Spiriferina octoplicata,	s		r	f	
,, ,, v. *biplicata*,		c			
,, *cristata*,		s			
,, ,, v. *octoplicata*,		r		f	
,, *insculpta*,		r			s
,, *laminosa*,	f		s	r	
Retzia ulstrix,		r			
Reticularia lineata,		c	c	c	c
,, ,, var. *reticulata*,		r			
,, ,, v. *elliptica*,		r			
Schizophoria (Orthis), resupinata varieties,		c		c	c
,, ,, ,, v. *gibbera*,		s			
,, ,, ,, ,, *globosa*,		s			
,, ,, ,, ,, *connivens*,		s			
,, *michelini*,	s			c	
Pugnus pleurodon,		c	c	c	c
,, ,, v. *davrenxiana*,		s			

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Names of Fossils.	Isle of Man.		Solway.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Brachiopoda—*continued.*					
Pugnus pugnus,		c	c	c	c
,, *acuminata*,		r			
,, ,, v. *plicata*,		r			
,, ,, ,, *platiloba*,		r			
,, *reniformis*,		r			
,, *angulata*,		c			
,, *flaxistria*,		r			
(s) ,, *trilatera*,		+			
Camarophoria globulina,		r		r	
,, *crumena*,		r	s	s	
Crania trigonalis,		r			
,, *quadrata*,		r	f	r	r
,, *ryckholtiana*,		s			
Orbicula (Discina) nitida,		r	s	c	c
,, ,, *craigii*,		r		r	
Dielasma hastata (colour bands),		c	c	c	c
,, ,, v. *saculus*,		c		c	r
,, ,, ,, *vesicularis*,		s		s	s
,, ,, ,, *gillingensis*,		c		s	r
,, ,, (very humid),		s			
Athyris royssi,		s	s	c	
,, *expansa*,		r			
,, *ambigua*,		c	f	c	c
,, *carringtoniana*,		s			
,, *globularis*,		s			
,, *squamigera*,		s			
,, *planosulcata*,		r	s	s	
Productus striatus,		f			
,, ,, (narrow v.),		f			
,, ,, (broad v.),		f			
,, *concinna*,		f		c	c
,, *semireticulatus*,		f		s	
,, *latissimus*,		s		f	c
,, cf. *pectinoides*,		r			
,, *scabriculus* (coarse v.),		r		f	
,, ,, (fine v.),		c	c	c	c
,, cf. *ermineus*,		r			
,, *fimbriatus*,	f	f	c	c	
(h) ,, cf. *corrugatus*,	+				
,, *cora*,		c	c	c	c
,, *margaritaceus*,		r			
,, *tessellatus*,		+			
,, *scoticus*,		f	s	c	c
,, *sinuatus*,		s		r	c
,, *undatus*,		r	r	r	r
,, *spinulosus*,		f		c	

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Names of Fossils.	Isle of Man.		Solway.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Brachiopoda—*continued.*					
Productus mesolobus,		c		s	r
,, *aculeatus*,		f		c	
,, cf. ,,		f			
,, *punctatus*,	f	f	c	c	r
,, *pustulosus*,	s	s		r	
,, *keyserlingianus*,		s			
,, cf. *marginalis*,		r			
,, *youngianus*,		f		c	r
,, *productus*,		s			
,, cf. ,,		s			
,, *plicatilis*,		r		r	
,, cf. *undiferus*,		s			
,, *elegans*,		c	c	c	
,, *muricatus*,		f		c	c
,, cf. ,,		r			
,, *sulcatus*,		f		c	c
,, cf. ,,		s			
,, *longispinus*,	s	s	c	c	c
,, *costatus*,		r	r	c	c
,, cf. ,,		r			
,, *hemisphericus*,		r	s		
,, *giganteus* (broad),	f			c	
,, ,, (rotund),		f	c	c	
,, *martini*,		f	c	c	f
,, Six new species,*		*			
cf. *Proboscidella mystiana*,		r			
,, *proboscidea*,		r			
Chonetes papilionacea,	f				
,, *polita*,	f		r	c	
,, *buchiana*,		s		r	r
,, cf. *hardrensis*,		s	f	c	c
,, *comoides*,		s			
,, sp. nov.,		r			
(h) *Strophomena (Leptæna) analoga*,	+				s
,, *rhomboidalis*,		s			
,, *(Leptæna) distorta*,		c			f
Cyrtina septosa,		r			
(h) *Syringothyris cuspidata* (Southernness),	+				
,, *distans*,		c			
Streptorhynchus (Orthotetes) cf. *senilis*,		s			r
,, *crenistria*,	c			c	c
,, ,, v. *robusta*,		r		r	r
,, ,, v. *rdialis*,		r		f	f
Schellwinella, sp. nov., *		r			

* Will be described by Dr. Ivor Thomas in his forthcoming Monograph on the Productidæ.

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Names of Fossils.	Isle of Man.		Sol-way.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Lamellibranchiata.					
Protoschizodus fragilis,		f			
(s) ,, *æqualis*,		+			
(s) ,, *impressus*,		+	s		s
,, *axiniformis*,		r	f	f	s
,, *trigonalis*,		r			
(s) ,, *subtruncatus*,		+		s	
,, *magnus*,		r			
,, *equilateralis*,		r		r	r
Schizodus, sp. nov.,		r			
Edmondia unioniformis,		c	r	f	f
,, *senilis*,		c	r	r	
,, *maccoyi*,		c	r	r	
,, *oblonga*,		f		s	
,, *scalaris*,		r		r	
,, *laminata*,		r			
,, *primæva*,		r		r	
,, *sulcata*,	r	r	r	f	
,, *lyelli*,		f		r	
,, *rudis*,		f	r	c	r
Cardiomorpha oblonga,		s		s	
,, *orbicularis*,		s		r	
,, *ovalis*,		s			
,, *egertoni*,		r			
(s) ,, *obliqua*,		+			
Lithodomas lingualis,		f	r	r	r
Sanguinolites plicatus,	r		s	s	s
,, *striatolamellosus*,		c	s	s	s
,, *theciformis*,		s			
,, *angustatus*,		r	r	r	
,, *omalianus*,		r		r	
,, *tricostatus*,		s	s	s	
(s) ,, *striatogranulosus*,		+		r	r
(s) ,, *subcarinatus*,		+		r	
,, v. *scripta*,	r			r	
Myalina lamellosa,		c			
,, *peralata*,		f		s	
Leiopteria laminosa,		c	s	s	s
,, *thompsoni*,		f			s
,, *pyreformis*,		s			
,, *lunulata*,		c	s	s	s
(s) ,, *informis*,		+			
(s) ,, *squamosa*,		+			s
,, *hirundo* (Millstone Grit),		s			
Allorisma monesis,	r	r			
Posidonella pyriformus,		s			
,, *elongata*,		r			

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Names of Fossils.	Isle of Man.		Solway.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Lamellibranchiata—*continued.*					
Posidonella vetusta,		c	r		r
,, *gibbosa*,		s			
,, sp. nov.,		r			
Posidonomya becheri (Calciferous of Scotland),		c			
Grammatodon reticulatus,		f		r	f
(s) ,, *bistriatus*,		+			
,, *squamiferus*,		f			
,, *obtusus*,		c	s	s	
,, *haimeanus*,		f			
,, *decussatus*,		f			
(s) ,, *verneulianus*,		+			
,, *fallax*,		c			
,, cf. ,,		c			
,, *friponti*,		c			
,, *theciformis*,		c			
,, *cingulatus*,		s			
(s) ,, *cancellatus*,		+			
(s) ,, *genitzi*,		+		r	f
Cypricardella annæ,		s			
,, *acuticarinata*,		s		f	s
,, *parallela*,		f			
,, *selysiana*,		s		r	r
,, *corrugatus*,		s			
Scaldia benedeniana,		r			
(s) ,, *visetensis*,		+			
Tellinomorpha cuniformis,		r		s	s
Mytilomorpha rhombea,		f		s	
Conocardium rostratum,		s		s	
,, *aliforme*,	s	s		s	
,, *inflatum*,		r		s	
,, sp. nov.,		r			
Solenomya primæva,		r		s	r
(s) ,, *costellata*,		+	r	r	
Pinna flabelliformis,		s	s	c	s
,, *mutica*,		s	s	s	
Limatulina desquamata,		s		r	r
,, *alternata*,		c	r		r
Palæolima simplex,		s	r	r	
,, *obliquiradiata*,		r			
,, *buchiana*,		s			
Aviculopecten carrolli,		r			
(s) ,, *arenosus*,		+		s	
,, *tabulatus* (colour bands),		c	r		
(s) ,, *cælatus*,		+		s	s
,, *stellaris*,		f		r	

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Names of Fossils.	Isle of Man.		Solway.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Lamellibranchiata—*continued.*					
Aviculopecten interstitialis,		f	r	r	r
(s) ,, *docens*,		+			
,, *tessalatus*,		r		r	r
(s) ,, *variabilis*,		r			r
,, *nobilis*,		r			
,, *murchisoni*,		c	f	s	s
,, *incrassatus*,		s		r	r
,, *dissimilis*,		f		s	r
,, *perradiatus*,		s			
,, *pera*,		s	s		
,, *plicatus*,		s		r	r
,, *semicostatus*,		s	s		r
,, *clathratus*,		f	s	s	s
(New Genus),		r			
Pterinopecten radiatus,		r	s	s	
,, *dumontianum*,		s			
,, *tessalatus*,		s			
,, *granosus*,		f		r	
,, *maleagrinoides*,		r	r		
,, *papyraceus*,		r			r
Pseudomusium sublobatum,		r			
,, *ellipticum*,		c		s	r
,, *anisotum*,		c	s	s	s
,, *gibbosum*,		r			
,, *concentricum*,		r	f	f	f
,, cf. ,,		r			
,, *auriculatum*,		s			
,, *concentrico-lineatum*,		r			
Syncyclonema sowerbyi,		f	r	r	r
Amusium concentricum,		r		r	r
Obliquepecten lævis,		s			
Eumicrotis hemisphericus,		s			r
Gasteropoda.					
Platyschisma ovoidea,		f			
,, *zonites*,		r		r	
,, *glabrata*,		r			
(s) ,, *helicoides*,		+			
,, 2 sp. nov.,		r			
(s) *Alcisma*, sp.,		+			
Naticopsis ampliata,		c			
,, cf. ,,		r			
,, *variata*,		f	c	c	c
,, *plicistria*,		c	r	r	r

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Names of Fossils.	Isle of Man.		Sol-way.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Gasteropoda—*continued.*					
Straparollus costellatus,		r			
,, *donysi*,		c			
(s) ,, *exalatus*,		+			
(s) ,, *pilopsideus*,		+			
Mourlonia goldfussi,		r			
,, *conica*,		+			
,, sp. nov.,		r			
(s) *Natrina lyrata*,		r			r
cf. ,, ,,		r			
Platyceras angustus,		r			r
(s) ,, *trilobus*,		+			
Macrocheilina conspicua,		r			
,, *sigmalinea*,		r			
,, *acuta*,		s	f	c	s
,, *imbricata*,		f		f	f
(s) ,, *rectilinea*,		+			r
Gosseletia, sp. nov.,		r			
Turbonellina, sp.,		r			
Ptychomphalus, sp. nov.,		r			
(s) ,, *sculptus*,		+			
Turbonitella biseralis,		s		r	
,, *ornata*,		r			
Capulus trilobus,		s			
,, cf. ,, (narrow),		r			
Lepetopsis retrorsus,		r			
,, *ellipticus*,		r			
,, cf. *phillipsi*,		r			
,, *curvatus*,		r			
,, *sinuosa*,		r			
Pleurotomaria cf. *flammingera*,		c			
(s) ,, *eliana*,		r			
Rhineoderma fragile,		r			
,, *gemmulifera*,		r			
,, sp. nov.,		r			
Luciella, sp. nov.,		r			
Phanerotinus, sp.,		f			
(s) *Microdoma serrilimba*,		r			
Entalis ornata,		r			
,, *herculea*,		s		s	
,, *ingens*,		r	r	s	
,, cf. *prisca*,		r		s	s
Metoptoma pileus,		r			
,, cf. *imbricata*,		r			
Chiton dalyensis,		r		s	
Rhombochiton, sp.,		r			

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Names of Fossils.	Isle of Man.		Solway.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Gasteropoda—*continued.*					
Schizostoma catillus,		r			
cf. *Rotellina planorbiformis*,		r			
Porcellia woodwardi,		s			
,, *puzo*,		f	r	r	r
Baylea, near *concentrica*,		r			
(s) ,, *leveilli*,		+			
,, *yvani*,		r		f	c
Loxonema rugifera,		r	r	f	
,, *constricta*,		c		r	
,, cf. *sulcatum*,		c			r
(s) ,, *scalaroidea*,		+		f	c
(s) *Portlockia parallela*,	+				
Euomphalus acutus,		f		r	r
,, *crotelostomus*,		r			
,, *pentangulatus*,		s	c	r	r
,, (depressed form),		r			
Heteropoda.					
Bellerophon hiulcus,		s	r	f	
,, *tenuifascia*,		c	f	r	r
,, *costatus*,		s	r		
,, cf. ,,		r			
,, cf. *tangentialis*,		s			r
(s) ,, *reticostatus*,		+			
Bucania striatus,		r	r	c	f
,, cf. *elegans*,		r			r
Euphemus urei,		r	r	r	c
Pteropoda.					
Conularia quadrisulcata,		r	r	r	r
Cephalopoda.					
Poterioceras fusiforme,		s		r	
(s) ,, *cordiforme*,	+			r	
Orthoceras cylindraceum,		f	r	r	r
(s) ,, cf. *acre*,		+			
,, *sulcatum*,		s	r	c	c
(s) ,, *affine*,		+			

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Names of Fossils.	Isle of Man.		Solway.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Cephalopoda—*continued.*					
Orthoceras cinctum,		s			r
,, *alticameratum,*		r			
,, *annulosobieatum,*		s			
(s) ,, cf. *martinianum,*		+			
(s) ,, cf. *salvum,*		+			
,, *muensterianum,*		f		r	
,, *inequiseptum,*		r			
(h) ,, *koninckianum,*		r			
(h) ,, *morrisianum,*		r			
,, *sollasi,*		r			
Cyrtoceras apicale,		s			
,, *unguis,*		f	r	r	r
,, *idoneum,*		s			
,, *ignotum,*		f			
(s) ,, *verneuilianum,*		+			
,, *(Meloceras) gesneri,*		f	r		r
,, sp. nov.,		r			
(s) *Actinoceras breynii,*		+			
,, *giganteum,*	r	r	r	r	r
(s) ,, *sowerbyi,*		+			
Apteloceras mutabile,		s			
Stoboceras subsulcatus,		f			
,, *sulcatus,*		f	r	c	r
(s) *Prolecanites compressus (Goniatites henslowi),*	r				
Cœlonautilus gradus,		r			
,, *planotergatus,*		f			
,, *cariniferous,*		f		s	
,, *derbiense,*		f			
(s) ,, *bistrialis,*		+			
(s) ,, *subsulcatus,*		+			
Temnocheilus coronatus,		r		r	r
,, *cricki,*		r			
,, sp. nov.,		r			
Thrinoceras hibernicus,		f			
Glyphioceras (Goniatites) crenistria,		c			
,, *vesica,*	+	r		r	r
,, *vesiculifer,*		r			
(s) ,, *implicatum,*		+			r
,, *mutabile,*		s			r
,, *micronotum,*		s		r	r
,, *obtusum,*		r			
,, *truncatum,*		f	r		
,, *striatum,*		f		r	r
,, *sphericum,*		f		r	r

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Names of Fossils.	Isle of Man.		Sol-way.	West of Scotland.	
	Lower Limestone.	Upper Limestone.	Arbigland.	Lower Limestone.	Upper Limestone.
Cephalopoda—*continued.*					
Solenocheilus dorsalis,	r	r			
(s) ,, *pentagonus*,	+				r
,, sp. nov.,		r			
(s) *Discites complanatus*,	+				
(s) ,, *bisulcatus*,		+			
(s) ,, *discus*,		+			
Phacoceras oxystomus,		r			
(s) *Ephippoceras bilobatum*,	+		r		
(s) *Gyroceras luidi*,		+			
,, *ornatissimus*,		r			
Nautilus globatus,		r	r	c	r
(s) *Pleuronautilus scarletensis*,	+				
Subclymenia evoluta,		r			
Nomisoceras, sp.,		s			
(h) *Discitoceras leveillanum*,	+	s			
Pisces.					
Polyrhizodus elongatus,	r				
Dicranodus dentatus,		r			
Ctenodus, sp.,		r			
Psammodus porosus,	r				
Psephodus magnus,	r			e	
(s) *Sphenacanthus*, sp. (in ash),					
Cladodus mirabilis,		r		c	f

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PROCEEDINGS OF THE GEOLOGICAL SOCIETY OF GLASGOW.

SESSION 1910-1911.

(Fifty-third Session.)

REPORT OF THE COUNCIL FOR 1909-1910.

(Submitted 10th November, 1910.)

Membership.—In submitting their Annual Report the Council would like to draw attention at the outset to the fact that there has been a somewhat serious falling off in the membership of the Society during the past session, there being ten members less on the roll this year than there were last year. The Council would therefore urge every member to do his utmost to recruit the ranks of the Society by making it his endeavour to add at least one new member to the roll.

The Finances will be reported upon by the Hon Treasurer (Mr. E. Hall Wight), and the Library by the Hon. Librarian (Mr. Wm. Sinclair).

Meetings.—During the session eight meetings were held, which were well attended. A number of important papers were contributed at these meetings, including the following:—Mr. A. L. Du Toit, on the "Geology of Cape Colony"; Mr. R. G. Carruthers, on "Zonal Work in the Lower Carboniferous Rocks, with Some Remarks on the Collection of Fossils"; Professor Gregory's Presidential address on "Work for Glasgow Geologists—the Problems of the South-Western Highlands"; Mr. John Smith's paper on "The Carboniferous Rocks of the Solway, Scotland"; and Mr. Dunlop's papers on "The Fossil Amphibia in the Kilmarnock Museum Previous to the Fire of 1909," and "Remarks on Some Crinoids."

Exhibits.—A large number of interesting exhibits of specimens were made at the various meetings throughout the session, and mention has again to be made of the extensive series of lantern slides of photographs illustrating the geological phenomena seen at the various localities visited by the Society during the year 1909, shown by Mr. Jas. W. Reoch.

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Transactions.—Part III. of volume xiii. of the *Transactions* was issued during last session, and Part I. of volume xiv. is now being printed off, and copies will be issued to the members at the next meeting.

Deaths.—During last session the Society lost five of its members by death. Mr. C. L. Dobbie, who died on the 10th July, 1910, joined the Society as a life member in 1883, and for a considerable time acted as a member of Council. Mr. Dobbie's business was that of a ship carver and gilder, and many fine figureheads for yachts and other craft were fashioned in his workshops in Paisley Road. Mr. Dobbie took no part in public affairs, but he was well known in Masonic and musical circles, and was also greatly interested in archæological and scientific questions. Mr. Dobbie, who was a native of the city, is survived by his widow and a son, the Rev. R. W. Dobbie, Blochairn United Free Church.

Mr. Archibald Donaldson, who died in America in the month of August, joined the Society in 1897, and also served for a period of three years as a member of Council. He took an active interest in everything that concerned the welfare of the Society, and was a regular attender of the meetings and excursions. Previous to joining this Society Mr. Donaldson was a member of the Glasgow Geological Field Club, and was one of the most enthusiastic of that small band of geologists who did so much to stimulate the study of geology in the city during the last decade of the nineteenth century. For the last few years of his life Mr. Donaldson suffered from a lung complaint, and, leaving his business in the hands of his son, he made two visits to America, and it was on the second of these that he died in that country.

Another member whose death we have to record was Mr. William Leighton, seed merchant and nurseryman, of 36 Renfield Street, who joined the Society in 1901. Mr. Leighton was an enthusiastic botanist, conchologist, and geologist. The other members removed by death during the past year were Mr. Joseph Chapman, of Hamilton, and Mr. James Barr, M.I.C.E., F.S.I., of Glasgow.

Excursions.—During the summer months fifteen excursions took place. It is to be regretted that these excursions have not been so well attended as the time and trouble spent on organising them would justify, and it is to be hoped that the members will take a greater interest in the excursion programme for next summer, and show their appreciation of the many privileges that are thereby offered them. The excursions were as follows:—

1. Kelvingrove Museum. Mr. Peter Macnair.
2. Girvan. Mr. R. Dunlop.
3. Glenboig. Prof. J. W. Gregory.
4. Dalmuir Burn. Mr. Peter Macnair.
5. Garelochhead. Prof. J. W. Gregory.
6. Hindog Glen. Mr. John Smith.

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7. Cadder Wilderness. Mr. Wm. Sinclair.
8. Arbigland. Mr. John Smith.
9. Auld Wives' Lifts, Craigmaddie Muir. Mr. Wm. Sinclair.
10. Lanark and the Falls of Clyde. Mr. G. W. Tyrrell.
11. Duntocher and Faifley. Mr. G. W. Tyrrell.
12. Paisley. Mr. D. P. M'Donald.
13. Tory Glen, Chapelhall. Mr. Motherwell.
14. Devol Glen, Port-Glasgow. Mr. David Chalmers.
15. Patna. Mr. G. W. Tyrrell.

SOCIETY'S ROOMS, 207 BATH STREET, 13TH OCTOBER, 1910.

The first meeting of the fifty-third Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., &c., *President*, in the chair.

The Minutes of the last meeting were read and adopted.

The following was elected as an Ordinary Member:—

Mr. Frank A. B. Preston, 16 Waverley Park, Shawlands, proposed by Mr. Peter Macnair and Mr. J. W. Reoch.

Professor GREGORY intimated with regret that Mr. Tyrrell would be unable to take an active part in the proceedings of the Society this session, owing to the state of his health, and that his paper on "Some New and Rare Rock Types in the West of Scotland" could therefore not be delivered this evening as had been intended.

Professor GREGORY also intimated the death abroad, during last summer, of Mr. Archibald Donaldson, an old member of the Society; and Mr. WILLIAM LYLE, who had been associated with him in the past at various classes, made feeling reference to this loss to the Society of a member who had taken a great interest in all branches of natural history.

Professor GREGORY also made reference to the death of Mrs. Robertson, widow of the late Dr. David Robertson, of Millport. She and her family had been intimately connected with the earlier work of the Society through association with her husband, and they had taken a great interest in the founding of the Marine Biological Station at Millport. It was agreed to send her son, Mr. Tom Robertson, an expression of the regret of the Society at her death. Mr. MACNAIR and Mr. STEEL also spoke with reference to her past association with the Society.

Mr. ROBERT DUNLOP exhibited specimens of *Loxonema sulcatula* (*M'Coy*) from the neighbourhood of Strathaven, a very rare species, and hitherto only recorded from one locality in the west of Scotland, viz., Bowertrapping. He also showed a collection of fossils from the Carboniferous Limestone of Poolvash Bay, in the Isle of Man. These included fine examples, some of them very large, of *Spirifera striata*, which had been weathered so as to show beauti-

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fully their internal spiral coils, a condition in which they are seldom found; also well-preserved specimens of *Spirifera glabra*, and various species of *Spiriferina*.

Mr. JAMES NEILSON spoke in reference to these specimens from the Isle of Man, remarking that three-quarters of the species found there are different from those obtained in Scotland, and they are generally much larger than the latter. They probably belonged to a different period and lived under purer oceanic conditions. Perhaps the Isle of Man species might belong to the earlier period of the Calciferous Sandstones. They might be of value in the zoning of the Carboniferous system.

Mr. R. G. CARRUTHERS also made remarks. He thought it would be quite impossible to correlate them with Scottish species, because the faunal facies were totally different.

Professor GREGORY referred to the Davidson collection in the Natural History Museum in London as containing perhaps the most perfect specimens in the world of *Spirifers*, showing their spiral coils as worked out by Mr. Glass.

Mr. ROBERT BOYLE, B.Sc., A.G.T.C., exhibited specimens of *Lithostrotion junceum* (*Ure*) from Crossflat, Muirkirk; *Productus giganteus* (*Martin*), from the same locality and from Glenmuir Limeworks, Cumnock; also *Carbonicola sp.* (*Anthracosia*), from Braehead Pit, Lugar, and described their characters.

Mr. JAMES W. REOCH, joint Hon. Secretary, showed Zeolites from Talisker, Skye, and read notes as to their occurrence there in the Tertiary basaltic lavas. The specimens included Scolecite (a mineral of rare occurrence in Scotland), Chabazite, Acadialite, Mesolite, Stilbite, and Analcime. Associated with some of these occurred crystals of Calcite, brown in colour and of an uncommon form, being acute rhombohedra with curved drusy faces, and these crystals had in some examples grown into bars stretching completely from side to side of the cavities in which they occurred, thus presenting the appearance of parallel growths in longitudinal series of polysynthetic acute rhombohedra. In some cases these bars had been completely enclosed in cleavage rhombohedra of clear Calcite of a later growth, through which the brown bars of Calcite were visible.

Mr. GEORGE WATSON exhibited specimens of post-glacial shells, including *Cyprina Islandica*, *Buccinum undatum*, *Balanus porcatus*, and *Leda pygmea*, found in a stiff black clay at 21 feet below the present level of the main road at Yoker. Remarks were made by Messrs. NEILSON, BOYLE, CARRUTHERS, STEEL, and DUNLOP on this interesting exhibit, and hopes were expressed that Mr. Watson would be able to throw further light on the relationship of the bed in which the shells occurred with others in the neighbourhood which had formerly been noticed.

Mr. R. G. CARRUTHERS, of H.M. Geological Survey, exhibited and described specimens of Annelid Tubes in sandstone from Calderwood

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Glen. These appeared to be very similar in character to the better known examples occurring at Giffnock.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., joint Hon. Secretary, showed a series of Geological Maps of Scotland, including those by M'Culloch, Knipe, Nicol, Murchison, and Geikie, and the later maps by Sir Archibald Geikie embodying the work of the Geological Survey. These were of great historical interest as recording the advances made during the last eighty years or so.

(Signed) J. W. GREGORY.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH NOVEMBER, 1910.

The second meeting of the fifty-third Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., *President*, in the chair.

The Minutes of the last meeting were read and adopted.

The Report by the Council, the Treasurer's Report, and the Librarian's Report for 1909-10 were then read, and, on the motion of Mr. E. W. Gemmell, seconded by Mr. James L. Begg, were unanimously adopted.

The following office-bearers were elected:—

Vice-President—Mr. Arch. A. Young, proposed by Mr. John Renwick and Mr. Wm. Sinclair.

Members of Council—Mr. Wm. Lyle, proposed by Mr. James Steel and Mr. Wm. Sinclair; Mr. James L. Begg, proposed by Mr. James W. Reoch and Mr. Peter Macnair; Mr. James Steel, proposed by Mr. Wm. Sinclair and Mr. Wm. M'Creath; Mr. A. B. Motherwell, proposed by Mr. J. Renwick and Mr. E. H. Hall Wight.

The following members were elected:—

As Associate Members—Mr. Duncan A. M'Vean, 28 Stewartville Street, Partick, proposed by Mr. P. Macnair and Mr. J. W. Reoch; Mr. J. D. Anderson, 2 Craignethan Gardens, Partick, proposed by Mr. P. Macnair and Mr. J. W. Reoch.

Mr. David Pearson and Mr. A. Macintyre were appointed as Auditors.

Mr. JOHN RENWICK gave notice that at next meeting he would move "that £15 of the Society's funds be granted for Library purposes."

Mr. ROBERT DUNLOP exhibited specimens of Cephalopods from Poullvash Bay, Isle of Man, including *Nautilus coronatus*, *N. compressus* and *N. levianus*, *Cyrtoceras tuberculatus*, *C. unguis*, *Orthoceras*, and several species of *Goniatites*. These were of special interest from their large size, as well as from the rarity of some of the species, and Mr. Dunlop was congratulated upon his discovery of them and thanked for bringing them before the Society.

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Mr. WILLIAM SINCLAIR, Hon. Librarian, read a paper on "The Relationship between the Raised Beach and the Boulder Clay of the West Coast of Kintyre." According to his view, the Raised Beach was older than the Glacial Period, the rock stacks on it being remnants of denudation when the sea was at the higher level. They are covered by the Boulder Clay, some almost entirely, while others are nearly bared, and in the background the clay hills rise to a height of 200 to 300 feet above sea level, the steeper declivities facing seawards and the more gentle slopes landwards. In some of the more precipitous parts landslips have occurred, and still occur. The paper was illustrated by numerous fine photographs taken by the author. In the discussion which followed, various members remarked on the novelty of the author's view, and a desire was expressed for further evidence on the subject.

Professor GREGORY, in welcoming Mr. Sinclair's paper as a contribution to the study of these Raised Beaches, suggested that an excursion of the Society might be made next year to the locality.

Professor J. W. GREGORY, D.Sc., F.R.S., President, contributed "Further Notes on the Scandinavian Overthrust," remarking that Scandinavia and Scotland are geologically closely akin, and the features common between them have been increased by the discovery that the older rocks in Scandinavia have been overthrust over the younger, as in our north-western Highlands. The movement, however, is claimed in Scandinavia on a scale much vaster than in Scotland. The existence of this movement has been asserted by the Swedish geologists, and, generally speaking, denied by the Norwegian. Three years ago, after a visit to the northern districts in question, Professor Gregory gave some account of the evidence, and then stated that the sections he had examined were absolutely convincing that overthrusting had occurred. During the present summer he examined some of the sections on which reliance is placed for the movements of the rocks from west to east for a distance of 140 miles, or twenty times as great as has been established in Scotland. He came to the conclusion that though overthrusting movements have occurred, and are larger than some Norwegian geologists are disposed to admit, they have not taken place on the scale that has been claimed for them.

In reply to questions by Mr. Macnair, Professor GREGORY stated that he was disposed to think the overthrusting in our north-west Highlands and in Scandinavia were both parts of one great movement.

Mr. JAMES NEILSON made reference to the intention of Mr. James Stark to start shortly on a sea voyage to the East for the benefit of his health, and the Society joined with Mr. Neilson in wishing him *bon voyage*, the Secretary being requested to convey him their good wishes.

(Signed) ARCH. A. YOUNG.

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SOCIETY'S ROOMS, 207 BATH STREET, 8TH DECEMBER, 1910.

The third meeting of the fifty-third Session of the Geological Society of Glasgow was held here this evening—Mr. ARCH. A. YOUNG, *Vice-President,* in the chair.

The Minutes of the last meeting were read and adopted.

Mr. JOHN RENWICK moved, in accordance with notice given by him at last meeting, that £15 of the Society's funds be granted for Library purposes. Mr. M'LEAN seconded, and the motion was carried unanimously.

The following members were elected:—

As Ordinary Members—Mr. Wm. Stevenson, jun., 13 Murray Place, Glasgow, S.S., proposed by Mr. Wm. M'Creath and Mr. Peter Macnair; Mr. George C. Watson, c/o Mrs. Kennedy, 478 St. Vincent Street, Glasgow, proposed by Mr. Peter Macnair and Mr. J. W. Reoch.

As Associate Members—Mr. John Wilson, West Arbuckle, near Airdrie; Mr. Arch. Fleming, jun., 17 Hutton Drive, Govan, South; Mr. John Leckie, c/o Mrs. M'Lauchlan, 16 Drive Road, Govan; Mr. James A. T. Garrioch, 41 Aitken Street, Dennistoun; Mr. Christopher Thomson, 167 Greenhead Street, Glasgow; Mr. H. H. Fraser, 87 West Campbell Street, Glasgow; Mr. George. H. Gordon, 14 Morrin Square; Mr. John S. Sharpe, Gowanbank, Millport; Mr. Wm. Miller, 23 Mar Street, Dennistoun; Mr. James Stewart, 49 Benview Street, Glasgow—all proposed by Mr. Peter Macnair and Mr. J. W. Reoch; and Miss Sara T. C. Leitch, 289 Byres Road, Glasgow; Miss Helen M'Ghee, 75 Elder Park Street, Govan; Mr. Alex. Fleck, Dean Terrace, Stepps; Mr. Farquhar MacRae, M.A., 5 Craignethan Gardens, Glasgow; Mr. William R. Smellie, M.A., Mayfield Villa, Mossend; Mr. Bryce K. N. Wyllie, M.A., Students' Settlement, 10 Possil Road, Glasgow—all proposed by Professor J. W. Gregory and Miss A. T. Neilson.

Mr. H. CONNACHER exhibited specimens of Volcanic Ashes from Mount Vesuvius, which fell in Naples in 1906, also specimens of Annelid Burrows from the Carboniferous rocks of the Forking Burn, Milton of Campsie, and made descriptive remarks on them.

Mr. ALEXANDER M'LEAN read a paper on "The Geology and Scenery of the Loch Maree Valley." In giving a general description of the district, he stated that there is not another region in Great Britain more fitted to excite an interest in geology than this valley. Its physical features could not fail to impress any one capable of admiring Nature on a grand scale. The ancient plateau of Torridon Sandstone and Cambrian Quartzite is almost worn down beyond recognition by the various denuding agents that were in constant operation during the long bygone geological ages. Two conspicuous remnants of the above-named plateau are Ben Slioch, on the north

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side of the valley, and Liathaich, on the south side of it. Then the dynamical geology is of surpassing interest. The evidence of the great horizontal displacement known as the Loch Maree fault is clearly seen. The strata on the north side of the valley rise in anticlines and synclines that may be easily traced along the south-eastern slopes of Beinn a' Mhuinidh, while on the south side the Torridon Sandstone and Cambrian Quartzite have been subjected to intense folding and reversed faults, and the strata are reduplicated in isoclinal folds. The Ben More thrust-plane on both sides of the valley can be readily seen; it is of great geological interest. The fossils found by the officers of the Geological Survey in the Cambrian shales of Meall a' Ghiubhais are also of great interest, as the trilobites of the genus *Olenellus* are the oldest crustaceans known on the globe.

Mr. DAVID P. M'DONALD, M.A., B.Sc., Baxter Demonstrator in the University of Glasgow, read a paper on "Microscopical Characters of Some Carboniferous Limestones." The Limestones specially referred to belong to the Lower Limestone Series, and they are mostly highly fossiliferous. The constituents of the matrix, however, cannot be distinguished by the unaided eye, but the microscopic sections show the nature of this matrix. The points noticed may be grouped as (1) the structure of the fossils; (2) the small organisms which cannot easily be recognised without the aid of the microscope; (3) the mechanical impurities and the changes which have taken place in the limestones. A number of slides were shown which illustrated the structures of the crinoids, brachiopods, corals, and polyzoa, and the smaller fossils noticed were the foraminifera and entomostraca. The sections showed that the secondary changes which have taken place in the limestones are less than might be expected. A little recrystallisation of the calcite, especially noticeable in the interior of the corals, polyzoa, and entomostraca is all the change observable in many of the sections. In other limestones, however, silicification has occurred. The nature of the matrix of several limestones was then noticed in more detail. The general conclusion was that although the individual limestones varied considerably, the contents of the matrix could be arranged in order of magnitude as crinoids, brachiopods, foraminifera, and polyzoa.

Professor GREGORY, in thanking Mr. M'Donald for his paper, expressed the hope that this work would be continued, remarking on the interesting results which such research yielded, especially as throwing a good deal of light on the mode of formation of the deposits.

Mr. MACNAIR also made remarks, alluding to the great work done in this direction in the past by the late Dr. John Young, of this Society, and to the fine collection of sections made by him.

The thanks of the Society were accorded to the various contributors.

(Signed) J. W. GREGORY.

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SOCIETY'S ROOMS, 207 BATH STREET, 12TH JANUARY, 1911.

The fourth meeting of the fifty-third Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., &c., *President*, in the chair.

The Minutes of the last meeting were read and adopted.

The following members were elected:—

As Ordinary Members—Mr. H. Priestley, 8 Glen View, Paisley, proposed by Mr. Wm. Sinclair and Mr. P. Macnair; Dr. Charles Auld, Kilwinning, proposed by Mr. Peter Macnair and Mr. J. W. Reoch.

As an Associate Member—Mr. Harry R. J. Connacher, 51 Grant Street, Glasgow, proposed by Mr. Peter Macnair and Mr. J. W. Reoch.

Professor J. W. GREGORY delivered his Presidential Address on "The Recent Glasgow Earthquake." [See *Transactions*, vol. xiv., p. 89.]

On the motion of Mr. CHRISTIE, seconded by Dr. SLOAN, a hearty vote of thanks was accorded Professor GREGORY for his address.

(Signed) J. W. GREGORY.

SOCIETY'S ROOMS, 207 BATH STREET, 9TH FEBRUARY, 1911.

The fifth meeting of the fifty-third Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., &c., *President*, in the chair.

The Minutes of the last meeting were read and adopted.

Mr. PETER MACNAIR, joint Hon. Secretary, exhibited on behalf of Mr. George T. Purves, specimens of Tenorite, contained in a piece of Highland schistose grit, obtained by Mr. George C. Watson from the boulder clay at Hamilton Hill. The mineral occurred as black inclusions, giving conclusive blowpipe reactions for copper, the bead of borax when containing a little organic matter giving that characteristic incandescence which is often seen on the liberation of oxygen at a high temperature under such circumstances. These evidences, combined with the fusing point of the specimen, its physical nature, and the mode of occurrence, lead to the conclusion that it is Tenorite (black oxide of copper). Mr. Macnair, in making further remarks on the specimen, showed for comparison an example of melaconite (oxide of copper) from the Leadhills, occurring in this case as a pseudomorph after copper pyrites.

Mr. HARRY R. J. CONNACHER exhibited specimens of Galena and Epsomite from Giffnock. The Galena was found in a bed of fireclay overlying the coal seam which occurs in Braidbar Quarry. It is of considerable interest as being the first record of the occurrence *in situ* of this mineral in Renfrewshire. The Epsomite was found in the fissures in the Giffnock sandstone (Liver Rock) in one of the columns of the tunnel, where it occurred as a light, needle-shaped efflorescence.

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Mr. MACNAIR read notes by Mr. G. T. Purves on the composition and probable origin of this specimen, in which he stated that the tests show that it contains fully 83 per cent. of hydrated sulphate of magnesia ($Mg\ SO_4\ 7\ H_2O$); there was present a little over 11 per cent. of sand, the remaining, about 6 per cent., being made up of moisture and a little sulphate of soda. The specimen showed only a minute trace of calcium when precipitated as oxalite. These two latter substances, calcium and sodium, would probably be present in the hydrated sulphate state similarly to the magnesium. As to the origin, it is well known that shale contains sulphur and sulphides, and it is considered that incipient oxidation has produced from them a sulphate. Water, possibly containing dissolved substances, has brought this sulphate into contact with the magnesium carbonate which is known to be present in the Giffnock sandstone, with the result that sulphate of magnesium has been formed, and it might also be that carbonate of iron has been precipitated at some other points. The solution of magnesium sulphate on coming into the crack has evaporated, producing the above efflorescence. This appears to be the probable explanation.

Mr. JAMES W. REOCH, joint Hon. Secretary, exhibited by lantern a series of photographs of the Tertiary igneous rocks of Skye. After giving a brief outline of the geology of the area covered by the illustrations, some of the more particular features were dealt with excursively. The districts included were Glen Sligachan, where the relations of the plutonic intrusions of gabbro and granite were exhibited, thence through the tract of volcanic agglomerate and the banded gabbro of Druim an Eidhne, and on to Loch Coruisg, where the effects of glaciation are to be seen on a grand scale as well as the fine mountain forms of the Cuillins. The views next exhibited were from the summit of Bruach na Frithe, whence a complete panorama of the Cuillin Hills was included, along with other views taken in a traverse of the main ridge westward to Bidein Druim nan Ramh, illustrating interesting points in the complicated structure of the gabbro laccolite, as well as comprehensive and more distant views of the great basalt plateau to the north-west. The granite intrusions were next viewed as seen from the summit of Glamaig and its neighbourhood, the marked contrast between the two types of scenery as determined by the nature of the rocks, gabbro and granite, being pointed out. Finally, the features of the basalt plateau were illustrated as seen in a traverse of the island from Sligachan to Talisker Bay on the west coast. The great sea-cliff near Talisker rises to a height of 900 feet and exhibits in a magnificent natural section the truncated ends of the basalt lava flows with their associated dolerite sills, the fallen blocks along the base being well known to mineralogists as a rich locality for beautiful specimens of zeolites, the larger cavities in the lavas containing crystals of very perfect form.

(Signed) JOHN RENWICK.

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SOCIETY'S ROOMS, 207 BATH STREET, 9TH MARCH, 1911.

The sixth meeting of the fifty-third Session of the Geological Society of Glasgow was held here this evening, Mr. JOHN RENWICK, *Vice-President*, in the chair.

The Minutes of the last meeting were read and adopted.

The following members were elected:—

As Associate Members—Mr. James Farquhar, 65 New Street, Stevenston, proposed by Professor Gregory and Miss A. T. Neilson; Mr. Andrew Barclay, 218 Great Western Road, and Mr. George J. Purves, 1375 Argyle Street, proposed by Mr. P. Macnair and Mr. J. W. Reoch.

Mr. R. G. CARRUTHERS, F.G.S., of His Majesty's Geological Survey, read a paper on "The Geology of East Kilbride." The paper was primarily of a stratigraphical nature, the object being to demonstrate the geological position of the strata in the East Kilbride district, which has for so long been classic ground to Glasgow palæontologists. At the outset reference was made to former work done in the district by the late Mr. James Bennie and Mr. Andrew Patton, as well as by Mr. James Neilson, of this Society; also to the memoir of the Geological Survey descriptive of Sheet 23. The strata are arranged in a simple syncline, and a complete sequence is seen along the river banks in Calder Glen. The Calderwood Limestones are correlated with the Hosie Limestones of the Glasgow district, and the Main Limestone with the Blackbyre Limestone of Hurlet. The Coulterland Coals are in the position of the Kilsyth Coking and Garibaldi Coals of Glasgow. It was shown that the strata correspond in a remarkable degree with those round Glasgow, although great variations in thickness are to be found. East of the Glen the Upper Limestone group is well developed in the faulted ground round Earnockmuir, and representatives of the Arden, Orchard, Lyoncross, and Index Limestones of Glasgow are all seen. An extensive overlap on to the Cathkin lavas exist, especially round Thorntonhall, where over 1000 feet of sediments found near Hurlet under the Blackbyre Limestone are missing. A description was given, and specimens exhibited, of the Pendleside fauna lately discovered in the Calciferous Series in Calder Glen below the Main Limestone. The specimens included *Posidonomya becheri* and *Pterinopecten papyraceus*. The paper was fully illustrated throughout by maps and sections.

Mr. JAMES NEILSON complimented Mr. Carruthers, and congratulated the Society on getting this paper from him. The sections described were fairly well known, but the correlation of the East Kilbride strata with the Hurlet section was quite new in our experience.

Mr. ROBERT DUNLOP thanked Mr. Carruthers for his able paper, and stated that this occurrence of *Posidonomya becheri* was the first record in Scotland.

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Mr. DAVID FERGUSON, M.I.M.E., in also thanking the lecturer for his paper, expressed a difference of opinion as to the correlation of the strata. The establishment of a connection between the Hurlet Limestone and what he recognised as the Gleniffer Limestone would settle the point, but that had not been done.

Mr. CARRUTHERS having briefly replied, on the motion of the Chairman a hearty vote of thanks was accorded him for his valuable communication, as well as for his diagrams, which he had kindly gifted to the Society. (Signed) ARCH. A. YOUNG.

SOCIETY'S ROOMS, 207 BATH STREET, 13TH APRIL, 1911.

The seventh meeting of the fifty-third Session of the Geological Society of Glasgow was held here this evening—Mr. ARCH. A. YOUNG, *Vice-President,* in the chair.

The Minutes of the last meeting were read and adopted.

The following was elected as an Associate Member:—Mr. W. Wylie Stewart, 312 W. Princes Street, proposed by Professor Gregory and Miss A. T. Neilson.

Mr. ROBERT DUNLOP exhibited the following specimens:—*Sphenopteris artemesiæfolioides,* from Baillieston and from Auchinleck; a new species of *Anthrapalæmon* from Greengairs, Airdrie; and a Crinoid head found at Ardross, near Elie, probably a new species belonging to the Cyathocrinidæ.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., read a paper on "The Perthshire Floods of August, 1910." [See *Transactions,* vol. xix., p. 115.]

Mr. JAMES NEILSON expressed his appreciation of this paper. No such records had hitherto appeared in the Society's *Transactions.* He briefly referred to other such instances of violent flooding, the effects of which he had seen in Arran, as well as in the neighbourhood of Ben Macdhui.

Mr. CHARLES R. COWIE also instanced phenomena of a similar nature which he had witnessed at Lochranza, and Mr. ROBERT DUNLOP referred to a like case of violent flooding at Kilmarnock in past years.

Mr. ROBERT W. DRON also spoke as to the importance of this paper, and referred to experiments which had been made as to the power of water in carrying débris through pipes; 1½ cubic feet of water had been found to carry 1 cubic foot of material through a 6-inch pipe inclined 1 foot in 10. He instanced the use of this power of water in placer-mining in California, &c.

Mr. ROBERT W. DRON, A.M.I.C.E., M.I.M.E., read "Notes on Bores at Manor Powis Coalfield, Stirling." The bores referred to were put down to prove the extension of the Bannockburn Coalfield

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to the north of the river Forth, where the coal seams approach the surface beyond the syncline of the Alloa Coalfield, and a study of them brought out several important points. In the Upper Coal Measures of the Alloa basin a series of east and west faults occur, by which the outcrops are thrown down successively to the south, forming the extensions of the coalfield by Kincardine and Airth, and thence to the Grangemouth and Falkirk Coalfields. The rise of the strata on the western margin of the basin brings the Carboniferous Limestone Series to the surface, and these strata are underlain and bounded on the west by a great sheet of basalt which forms the Abbey Craig and Stirling Castle rock, and stretches southward, forming the hills to the west of Denny. Beneath this intrusive sheet a seam of limestone crops out, corresponding with the Hurlet Limestone, and forming the base of the Carboniferous Limestone Series. This basaltic sheet seems to be somewhere about 350 feet thick, and appears to maintain its position with considerable regularity between the Hurlet Limestone and the overlying coal seams. Its outcrop has been shifted by the east and west faults in the same way as the outcrops of the coal seams, and to one or more of these faults is likely due the gap through which the river Forth now flows between Stirling and Causewayhead. In the various bores put down the strata were found to be very uniform. The limestones met with were correlated with those in the Glasgow district, from the Castlecary Limestone down to the Index Limestone, and beds of sandstone were also found corresponding more or less with the Barrhead, Bishopbriggs, and Cowlairs sandstones. An examination of the cores for fossils brought out the important fact of the presence of representatives allied to the marine fauna of Nebraska and other American States—viz., in the Castlecary Limestone of *Schizodus wheeleri* and in the Index Limestone of *Protoschizodus curtus* and *Prothyris elegans*. Hitherto these fossils have not been found in any Scottish strata lower than a few fathoms above the Castlecary Limestone. To the presence of the basaltic sheet the author attributed the anthracitisation, to a greater or less extent according to their distance from it, of the various coal seams shown in the several bores, this being brought about by heat at the intrusion of the sheet. In one instance a thin seam in contact with the whin was reduced to graphite. Some thin beds of coal within 200 feet of the underlying basalt have been burnt beyond the anthracite stage, while from this point upwards the six succeeding coal seams show regular gradation as they are found farther from the whin. The lower seams are anthracite, the middle seams coking coals, and the upper seams bituminous coals. Anthracite coals are found in many parts of Scotland, both in the Coal Measures and in the Carboniferous Limestone Series, and the author has found these invariably associated with intrusive whinstone. He strongly expressed his opinion that the anthracitisation is entirely owing to the presence of the whin, and he could not agree with the

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opposite conclusion as stated in the Summary of Progress of the Geological Survey of Great Britain, 1908.

Mr. CHARLES R. COWIE remarked with reference to the anthracitisation of the coals that if this were due to the presence of intrusive rock you would expect to find the products of distillation deposited in the surrounding strata, and he instanced observed cases of such natural processes from the oil-shale group. In the absence of such it would leave the question open to doubt.

Mr. ROBERT DUNLOP spoke as to coals containing the same percentage of volatile matter being some of coking and others of non-coking quality. He accounted for this from the resins of lower melting-point having been driven off and those of higher melting-point remaining.

Mr. DRON, in replying, stated that in the bore cores no tarry matters had been found; but they might be found in the workings. He was pleased to have Mr. Dunlop's explanation as to the coking and non-coking coals. (Signed) ARCH. A. YOUNG.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH MAY, 1911.

The eighth meeting of the fifty-third Session of the Geological Society of Glasgow was held here this evening—Mr. ARCH. A. YOUNG, *Vice-President*, in the chair.

The Minutes of last meeting were read and adopted.

The CHAIRMAN brought before the meeting a proposal for Life Membership by Mr. Peter Innes, 5 Ibrox Place, under exceptional circumstances as discussed by the Council at their meeting to-night, at which it had been agreed that, subject to the approval of the Society, Mr. Innes be admitted. On the motion of Mr. ROBERT DUNLOP, Mr. Innes was now unanimously elected a Life Member.

Mr. JAMES NEILSON exhibited a geological map of the island of Arran as a specimen of the new system of colour-printing now adopted by the Geological Survey, and drew attention to the several features of interest in it.

Mr. JOHN SMITH exhibited specimens of Andalusite-schist from Poundland Burn, Colmonell, and from Skiddaw, Cumberland.

Mr. JOHN SMITH also read a paper on "The Carboniferous Rocks of the Isle of Man." [See *Transactions*, vol. xix., p. 119.]

Mr. Smith was heartily thanked for his communication.

The meeting then adjourned till next Session.

EXCURSIONS FOR SEASON, 1911.

To Kelvingrove Museum, on Saturday, 8th April—Mr. Peter Macnair, F.R.S.E., F.G.S., conductor. The party met in the Geological Gallery at 3 p.m. and examined the recent additions to the Geological Collection, including a fine collection of minerals from Wanlockhead, and specimens from the Tertiary Leaf Beds of Mull.

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To New Luce, Wigtownshire, on Monday, 17th April (Spring Holiday)—Mr. John Smith, conductor. The object of the excursion was to examine one of the great Ordovician bands of Graptolite shale which crosses the main Water of Luce two miles north of New Luce at Kilfeather Loup. Specimens are here abundant and in fine preservation. Sections of the Greywackes were seen on the Luce Water.

To Ballagan, Stirlingshire, on Saturday, 22nd April—Mr. J. W. Reoch, conductor. The chief object of the excursion was to examine the fine cliff section of rocks belonging to the Calciferous Sandstone Series, known as the "Ballagan Beds." These consist of a series of thin-bedded deposits, containing "upwards of 230 beds of limestone, sandstone, and marly shales, seen to lie, tier upon tier, in a slightly inclined position, and capped by massive sandstones." ("Campsie," by the late Dr. John Young, F.G.S.; *Transactions*, vol. i.) None of the limestone beds is above 1 foot thick; they are nodular and dolomitic, containing about 17 per cent. of magnesia. Varieties of gypsum occur in the beds—one impure, massive, reddish; another pure, white, fibrous, and a third yellowish, fibrous. The whole group is overlaid by the extensive lava flows of the Campsie Hills. A powerful fault throws down the lavas in the Blane Valley, to the south of which they are overlaid by the conglomerates and sandstones at the base of the Carboniferous Limestone Series. In the centre of the valley is Dunglass, a conical hill of basalt, showing fine columnar structure.

To Douglas Muir, Dumbartonshire, on Saturday, 6th May—Mr. R. W. Dron, A.M.I.C.E., M.Inst.M.E., conductor. The object of the excursion was to observe the influence of the geological structure on the scenery, due to the outcrops of the lava flows of the Kilpatrick Hills, and the overlying glacial deposits.

To Calder Glen, East Kilbride, on Saturday, 13th May (joint excursion with Airdrie Naturalists' Society)—Mr. R. G. Carruthers, F.G.S., conductor. The chief object of the excursion was to examine sections in the Lower Limestone Series on the river banks below Calderwood Castle, where representatives of the Thorntonhall Limestones are exposed, which it is believed have not been previously recognised. Attention was also given to the underlying Calciferous strata, containing a limestone of Pendleside type, with *Posidonomya becheri*, and other fossils new to the west of Scotland. Further up the glen flaggy sandstones were seen, crowded with annelid burrows, and the well-known sections of the Calderwood Limestones, south of the Castle, were also visited.

To Aberfoyle, Perthshire, on Thursday, 25th May (Victoria Day)—Mr. Peter Macnair, F.R.S.E., F.G.S., conductor. The party walked to Kelty Water and Corrie Burn, examining *en route* the fine sections exposed in the Ballimore Burn of the Jasper beds, Black Shales, Cherts and Grits of supposed Arenig age, flanked on the north by the Leny Grit, and on the south by the Lower Old Red Conglome-

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rates and Andesites. The ridge of hills was also examined. Intrusions of Dolerite occur along the line of the great Boundary Fault, and a sill of Hornblende-schist occurs along with the Arenig rocks. The neighbourhood shows some striking examples of the dependence of scenery upon geological structure.

To Arthur's Seat, Edinburgh, on Saturday, 3rd June (joint excursion with Edinburgh Geological Society)—Dr. B. N. Peach, F.R.S., F.G.S., past President, conductor. The object of the excursion was to show the evidence for the geological age of the Arthur's Seat Volcano, the succession of lavas and ashes exposed in the Dry Dam and the Whinny Hill, and to point out the two necks or vents from which these lavas and ashes were in all probability successively extruded.

To Luss, Loch Lomond, on Saturday, 10th June—Dr. Gregory, F.R.S., F.G.S., President, conductor. The object of the excursion was to examine the Luss slates and the adjacent rocks mapped by the Geological Survey as part of the Schist Series.

To Cathkin Braes, on Tuesday, 20th June (evening excursion)—Mr. Robert Boyle, B.Sc., F.G.S., conductor. The party proceeded by East Kilbride Road to Cathkin, where there are large quarries in Carboniferous lavas and tuffs. Columnar structure in the basalt is beautifully shown. There is a variety of coarse tuff called "Osmund-stone." Saponite occurs in veins, bright green, transversely fibrous (Young); also in lenticular nodules up to 8 inches across, at the base of the quarry, brown, massive, with conchoidal fracture ("Cathkinite," J. J. Dobbie, *Transactions*. Geological Society, Glasgow, vii., p. 166, 1883); and in the porphyritic lava, in small druses, with Labradorite, Olivine and Ferrite (Heddle, *Mineralogy of Scotland*, vol. ii., p. 141). On Cathkin Braes the lava, as poured out in successive terraces, was examined.

To Bishopbriggs, on Thursday, 29th June (evening excursion)—Mr. G. C. Watson, conductor. The object of this excursion was to examine a fine section of the Bishopbriggs sandstones, shales, and limestones, exposed in a cutting of the North British Railway, south of the station. This section is described and figured by Professor Young and Dr. Young (*Transactions*, Geological Society of Glasgow, vol. ii., p. 283). The strata exposed belong to Possil Coal and Iron stone Series, and to the Upper Limestone Series. In Huntershill Quarry a fossiliferous limestone, probably the local equivalent of the Orchard Limestone, was examined. There are interesting crumplings and unconformities, also a forked dyke with columnar sandstone.

To Clydebank Waterworks and The Whangie, Dumbartonshire, on Saturday, 5th August—Mr. N. Martin, B.Sc., A.M.I.C.E., and Mr. R. Boyle, B.Sc., A.M.I.C.E., conductors. A puddle trench, partly open, and excavations for an overflow channel, in which striated surfaces are abundantly found, were visited. A section is open in a large boulder clay hill, where materials are obtained for puddle and

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embankment. In Burn Crooks and its tributaries, leading up to the works, may be seen good agglomerate and tuff, with Calciferous Sandstones, dykes, &c. There are fine sections in boulder clay and thick peat. The great landslip known as The Whangie was also visited.

To New Pit, near Prestwick, on Saturday, 19th August—Mr. D. Ferguson, M.I.M.E., conductor. By kind permission of Messrs. Wm. Baird & Co., Ltd., the party examined the Coal Measure sandstones and shales at their new pit at present being sunk near Prestwick. The "trap" dyke on the Prestwick shore was also visited. It is thought to extend for 190 miles.

To the Lang Craigs, Dumbarton, on Saturday, 26th August—Mr. G. W. Tyrrell, A.R.C.S., F.G.S., and Mr. H. R. J. Connacher, conductors. A great series of contemporaneous lava-flows are here seen, the truncated edges of which are well exposed along the Lang Craigs. An outlier behind Craigendoran indicates that they once extended much further west, but have been removed by denudation. Some of the flows are honeycombed with gas cavities, in which various Zeolitic minerals have been crystallised from aqueous solution. Specimens may be obtained from the screes at the base of the Craigs. The lavas rest on the Ballagan shales and dolomites as seen in Auchinreoch and Dumbuck Glens, which in turn rest on the Upper Old Red Sandstones of Dalreoch.

To the Scottish Exhibition of History, Art, and Industry, Glasgow (evening excursion), on Thursday, 14th September—Mr. John Renwick, conductor. The party examined the exhibits of geological and archæological interest, which included a collection of pre-historic slags from the early bloomeries, and attended a lecture by Dr. Cecil H. Desch on "Pre-historic Metal Working in Scotland."

To Loch Doon and Ness Glen, Dalmellington, Ayrshire, on Monday, 25th September (Autumn Holiday), joint excursion with Geographical Section of Royal Philosophical Society of Glasgow—Mr. Frederick Mort, M.A., B.Sc., F.G.S., F.R.S.G.S., conductor. Dalmellington is situated at the edge of the Coal Measures which, near the village, are faulted against lavas of Old Red Sandstone age. The party proceeded up the Doon Valley, passing across a strip of Old Red Sandstone, and thence to Ordovician Rocks which are here thrown on end. Ness Glen, one of the finest canyons in Scotland, was seen *en route*, and the question of its origin discussed. Splendid examples of glacial erosion are visible about Loch Doon, and the scenery around the loch is typical of the Southern uplands at its best. Several features of considerable geographical interest were noticed.

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ABSTRACT OF THE TREASURER'S ACCOUNTS FOR THE YEAR ENDED 30TH SEPTEMBER, 1910.

CASH ACCOUNT.

RECEIPTS.

To Subscriptions for current year (including 9 new Ordinary Members)—145 at 10/,	£72	10 0
,, Do. 3 at 7/6,	1	2 6
,, Do. Arrears—5 at 10/,	2	10 0
,, Life Membership Subscription,	5	5 0
,, Associate Members' Subscriptions—7 at 2/6,	0	17 6
,, Mitchell Library for copies of *Transactions* and Jubilee Volume,	8	5 10
,, Sales of do., per Hon. Librarian,	1	13 3
,, Interest on Funds, £7 0 3		
,, Do. Mr. C. R. Cowie's Donation, 2 0 7		
	9	0 10
,, Mortgage for £100 with Campbeltown Corporation over Gas Works at 3½ per cent. realised,	100	0 0
	£201	4 11

EXPENDITURE.

By Balance due Treasurer at close of last Account,		£4	3 8
,, *Transactions*—			
Printing and Publishing Vol. XIII., Part 3,	£55 13 10		
Postages and Outlays *re* do.,	2 18 5		
		£58	12 3
,, Library—New Books and Bookbinding,		13	2 6
,, Printing and Postage of Circulars and Excursion Booklets, and Advertising,		19	11 6
,, Rent, Insurance, and Attendance,		16	10 0
,, Voted by Society to close Jubilee Account,		13	10 0
,, Disbursements by Hon. Secretaries, Postages, Stationery, and Petty Expenses,		5	8 2
,, Lantern Expenses,		1	10 0
,, Subscription to Marine Biological Association, 1910,		1	1 0
,, ,, to Palæontographical Society, 1910,		1	1 0
,, Cash in Bank on Deposit,	£60 0 0		
,, Cash in Treasurer's Hands,	4 14 3		
,, Do. Mr. C. R. Cowie's Donation,	2 0 7		
		66	14 10
		£201	4 11

JUBILEE CELEBRATION ACCOUNT.

Sept. 30, 1910.—To Subscriptions,	£0	18 6
,, Amount voted by Society to close Account,	13	10 0
	£14	8 6

Oct. 1, 1909.—By Balance due Treasurer at close of last Account,	£14	8 6
	£14	8 6

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LIFE SUBSCRIPTION ACCOUNT.

Sept. 30, 1910.—To Amount voted to close Jubilee Fund, ..	£13	10	0	October 1, 1909.—By Balance, ...	£183	10	0
,, Balance to Credit, ...	175	5	0	Sept. 30, 1910.— ,, Subscription during Year, ...	5	5	0
	£188	15	0		£188	15	0

Mr. CHARLES R. COWIE'S DONATION.

Sept. 30, 1910.—To Glasgow University, one-half of accrued Interest to 30th September, 1909, ...	£1	10	11	Oct. 1, 1909.—By Investment with the Corporation of Campbeltown on Gas Works Mortgage at 3½ per cent.,	£100	0	0
,, Glasgow & West of Scotland Technical College, one-half of accrued Interest to do.,	1	10	10	,, Interest on do. to date, ...	3	1	9
Balance to Credit, ...	102	0	7	Sept. 30, 1910.—Interest accrued to 13th May, 1910, ...	2	0	7
	£105	2	4		£105	2	4

STOCK ACCOUNT.

To Life Subscription Account, ...	£175	5	0	By Investment with Campbeltown Corporation under Mortgage at 3½ per cent., ...	£170	0	0		
,, Mr. Charles R. Cowie's Donation and accrued Interest, ..	102	0	6	,, Cash in Bank and in Hand, ...	64	14	3		
,, Capital Account,*	559	9	4					£234	14 3
				,, Property—Books in the Library, ...	£440	0	0		
				Furniture, Bookcases, & Microscope,	60	0	0		
								500	0 0
				,, Mr. Charles R. Cowie's Donation—Invested with Campbeltown Corporation under Mortgage at 3½ per cent., ...	£100	0	0		
				,, Do., Interest accrued to Whitsunday, 1910, ..	2	0	7		
								102	0 7
	£836	14	10					£836	14 10

* NOTE.—Subject to cost of publishing *Transactions*.

GLASGOW, *4th November*, 1910.—Examined, compared with relative Vouchers and Securities, and found correct, the balance in Treasurer's hands being Six Pounds Fourteen Shillings and Tenpence; Four Pounds Fourteen Shillings and Threepence being due to the Society, and Two Pounds and Sevenpence being Interest accrued on Mr. Charles R. Cowie's Donation.

D. PEARSON,
ARCH. A. YOUNG, } *Auditors.*

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THE GEOLOGICAL SOCIETY OF GLASGOW.

OFFICE-BEARERS FOR SESSION 1910-1911.

President—

Prof. J. W. GREGORY, D.Sc., F.R.S., F.G.S.

Vice-Presidents—

For Three Years.

Mr. ARCHIBALD A. YOUNG.

For Two Years.	*For One Year.*
Mr. JOHN RENWICK.	Mr. F. MORT, M.A., B.Sc., F.G.S.

Members of Council—

Mr. WM. LYLE.	Mr. WM. M'CREATH.	Mr. R. W. DRON.
Mr. JAMES L. BEGG.	Mr. ALEX. M'LEAN.	Mr. JOHN M'KELLAR.
Mr. JAMES STEEL.	Mr. D. P. M'DONALD.	Mr. JAMES STARK.
Mr. A. B. MOTHERWELL.	Mr. M. M. MONIE.	Mr. ROBERT BOYLE.

Honorary Secretaries—

Mr. PETER MACNAIR, F.R.S.E., F.G.S., Kelvingrove Museum.

Mr. JAMES W. REOCH, 22 Montgomerie Street, Kelvinside.

Honorary Treasurer—

Mr. E. HALL WIGHT, 150 Hope Street.

Honorary Librarian—

Mr. WILLIAM SINCLAIR, 47 Oswald Street.

Honorary Editors of "Transactions"—

Mr. PETER MACNAIR. | Mr. JAMES W. REOCH.

Auditors—

Mr. DAVID PEARSON. | Mr. A. MACINTYRE.

COMMITTEES APPOINTED BY THE COUNCIL.

Printing and Publishing Committee—

Professor Gregory, Messrs. E. Hall Wight, Joseph Sommerville, R. W. Dron, F. Mort, Archibald A. Young. P. Macnair, *Convener.*

Library Committee—

Messrs. Joseph Sommerville, James Steel, David Chalmers, James Stark, James Anderson, M. M. Monie, Alexander M'Lean, Wm. Lyle, Robert Boyle. Wm. Sinclair, *Convener.*

Excursions Committee—

Professor Gregory, Messrs. R. W. Dron, David Chalmers, John Renwick, Joseph Sommerville, Robert Dunlop, William M'Creath, D. P. M'Donald, A. B. Motherwell, James L. Begg. Robert Boyle, *Convener.*

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Messrs. A. Macintyre, Joseph Sommerville, John M'Kellar, R. W. Dron. E. Hall Wight, *Convener.*

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The Honorary Secretaries are "ex-officio" Members of all the above Committees.

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LIST OF MEMBERS.

(As at December, 1911.)

Honorary Members.

Year of Election.

1863. Geikie, Sir Archibald, D.C.L., LL.D., F.R.S., &c., Shepherd's Down, Haslemere, Surrey.

1867. Woodward, Henry, LL.D., F.R.S., F.G.S., 13 Arundel Gardens, Notting Hill, London, W.

1867. Jones, T. Rupert, F.R.S., F.G.S., 17 Parson's Green, Fulham, London, S.W.

1871. Hull, Edward, M.A., LL.D., F.R.S., F.G.S., 20 Arundel Gardens, Notting Hill, London, W.

1883. Judd, J. W., C.B., LL.D., F.R.S., F.G.S., 22 Cumberland Road, Kew, London.

1888. Murray, Sir John, K.C.B., LL.D., F.R.S., F.R.G.S., Challenger Lodge, Wardie, Edinburgh.

1900. Gray, Mrs. Robert, 59 George Street, Edinburgh.

1902. Geikie, James, LL.D., D.C.L., F.R.S., F.G.S., F.R.G.S., Kilmorie, Colinton Road, Edinburgh.

1902. Horne, John, LL.D., F.R.S., F.G.S., 12 Keith Crescent, Blackhall, Midlothian.

1902. Lapworth, Charles, LL.D., F.R.S., F.G.S., University of Birmingham.

1902. Peach, B. N., LL.D., F.R.S., F.G.S., Geological Survey Office, Edinburgh.

1902. Traquair, R. H., M.D., LL.D., F.R.S., F.G.S., The Bush, Colinton, Edinburgh.

1904. Jolly, Wm., F.R.S.E., Blantyre Lodge, Blantyre.

1907. Murdoch, Mrs. J. B., Capelrig, Newton Mearns.

1908. Bonney, Prof. T. G., Sc.D., LL.D., F.R.S., F.G.S., 9 Scroope Terrace, Cambridge.

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Year of Election.

1909. Smith, John, Dykes, Dalry, Ayrshire.

1909. Suess, Eduard, Vienna.

1909. Hind, Wheelton, M.D., B.S., F.R.C.S., Roxeth House, Stoke-on-Trent.

Corresponding Members.

1864. Mitchell, Rev. Hugh, LL.D., Craig, Montrose.

1867. Kerr, David, Wemyss Colliery, Fifeshire.

1871. Jack, R. L., LL.D., F.G.S., 36 Overstrand Mansions, Battersea Park, London.

1871. Jamieson, T. F., F.G.S., Ellon, Aberdeenshire.

1883. Scott, Thomas, F.L.S., Menzies Road, Torry, Aberdeenshire.

1884. Dobbie, J. J., M.A., D.Sc., Royal Scottish Museum, Edinburgh.

1884. Nathorst, Professor Alfred Gabriel, Stockholm, Sweden.

1898. Livingston, Colin, Ardtraigh, Fort-William.

1909. Young, James, Lesmahagow.

Ordinary Members.

[An asterisk (*) indicates a Life Member.]

1909. Alston, Cauvin S., 20 Easwald Bank, Kilbarchan.

1905. Anderson, E. M., M.A., B.Sc., H.M. Geological Survey Office, 33 George Square, Edinburgh.

1882. Anderson, James, Thorn Road, Bearsden.

1908. Anderson, P. J., M.A., LL.B., University Library, Aberdeen.

1910. Auld, Dr. Charles, Holmwood, Kilwinning.

1898. Bain, James, The Whins, Alloa.

1911. Barclay, Andrew, F.E.I.S., Possilpark Public School, Possilpark.

1894.*Barlas, George, 15 Ruthven Street, Glasgow.

1894.*Barr, Professor Archibald, Royston, Dowanhill, Glasgow.

1893. Barr, Patrick, 51 Bath Street, Glasgow.

1907. Bayne, J. A. C., Jamadoba Colliery, P.O. Jharia, E.I. Railway, India.

1903. Beattie, William, Dineiddwg, Milngavie.

1905. Begg, James L., Elms, Mount Vernon.

1906. Bennett, Professor Peter, Technical College, George Street, Glasgow.

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Year of Election.

1908. Boyle, Robert, B.Sc., F.G.S., Engineer's Office, Commissioners for the Port of Calcutta, Calcutta.

1895. Brown, Rev. Alex., 4 Leslie Road, Pollokshields.

1909. Brown, George A., 35 Sunnyside Road, Coatbridge.

1904. Buchanan, R. M'Neil, M.B., C.M., F.F.P.S.G., Corindi, Scotstounhill.

1904. Buchanan, W. Arthur, 14 Hillhead Gardens, Hillhead.

1894. Burnett, John James, A.R.S.A., 70 University Avenue, Hillhead.

1902. Burns, Daniel, M.I.M.E., Technical College, George Street, Glasgow.

1907. Campbell A. G., Artesian Works, Inchicore, Dublin.

1903. Campbell, Bailie Arch., Springfield Quay, Glasgow.

1877. Campbell, John MacNaught, 6 Franklin Terrace, Sandyford.

1905. Carmichael, John, 1399 Argyle Street, Glasgow.

1880. Carmichael, Robert S., Audit Office, St. Enoch Station, Glasgow.

1906. Carruthers, R. G., F.G.S., H.M. Geological Survey Office, 33 George Square, Edinburgh.

1895. Chalmers, David, 16 Berkeley Terrace, Glasgow.

1903. Clarkson, William, Quarrymaster, Friar's Park, Lesmahagow.

1905.*Clough, C. T., M.A., H.M. Geological Survey Office, 33 George Square, Edinburgh.

1891. Cowie, Charles R., Woodend, Partickhill.

1900.*Cozens, Samuel F., Salem, Skelmorlie.

1907. Currie, Robert, A.G.T.C., M.I.M.E., 32 M'Lelland Drive, Kilmarnock.

1894. Dixon, Walter, Derwent, 30 Kelvinside Gardens, Kelvinside.

1907. Donald, W., The Eglinton Silica Brick Co., Ltd., Dundyvan, Coatbridge.

1881.*Dougan, John, 27 Smith Street, Hillhead.

1887. Dow, William, 17 Sommerville Drive, Mount Florida.

1895. Dron, R. W., A.M.I.C.E., 55 West Regent Street, Glasgow.

1906. Drummond, John, 35 High Street, Airdrie.

1883. Dunlop, Robert, Rosemont, Weirwood Park, Shettleston.

1901. Du Toit, Alex. L., B.A., Geological Commission, South African Museum, Cape Town, S.A.

1909. Elliott, Alex., 87 Holmlea Road, Langside.

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Year of Election.

1901. Faill, John, 7 Winton Drive, Kelvinside.
1911. Falconer, Dr. J. D., M.A., F.G.S., F.R.S.E., Lecturer on Geography, The University, Glasgow.
1898. Fergus, A. Freeland, M.D., 22 Blythswood Square, Glasgow.
1906.*Ferguson, Professor, M.A., LL.D., 13 Newton Place, Glasgow.
1897. Fingland, Samuel, Braehead Villa, Cathcart.
1911. Fleck, Alex., B.Sc., Dean Terrace, Stepps.
1898.*French, Thomas, 1 Kelvinside Terrace, Kelvinside.

1901. Gale, William M., C.E., 1 Athole Gardens Place, Kelvinside.
1887. Gardner, John, 65 Great Clyde Street, Glasgow.
1901. Gemmell, E. W., 82 Langside Avenue.
1894.*Gilfillan, William, 185 St. Vincent Street, Glasgow.
1908. Gilmour, Matthew B., Saffronhall House, Hamilton.
1873.*Gilmour, Thomas, M.D., Port Ellen, Islay.
1895. Glen, Alexander, 25 Dumbreck Road, Glasgow.
1894. Goldie, James, J.P., 52 St. Enoch Square, Glasgow.
1877.*Graham, M. M., 21 Bath Street, Glasgow.
1904. Gray, John, 6 Roodelloam Gardens, Clarkston, Busby.
1904.*Gregory, Prof. John Walter, D.Sc. F.R.S., F.G.S., Prof. of Geology, Glasgow University.

1907. Hall, Rev. Charles A., Meersbrook, Meikleriggs, Paisley.
1872. Hamilton, Arch., C.E., Clyde Navigation Office, 16 Robertson Street, Glasgow.
1907. Harper, Robert, Friarbank Terrace, Dunbar.
1876. Henderson, John, J.P., Ballochmorrie, Pinwherry, South Ayrshire.
1908. Hendry, David, Dunmore, Thomson Avenue, Johnstone.
1903. Hill, Alexander, 11 Dolphin Road, Pollokshields.
1877. Hislop, George R., F.C.S., F.R.S.E., Greenhill House, Paisley.
1891. Hodge, William, 27 Montgomerie Drive, Kelvinside.
1897. Houston, Robert S., 61 New Sneddon Street, Paisley.
1894. Hubbard, John James, 9 Bute Mansions, Hillhead.
1894. Hubbard, Walter Raglan, 9 Broomhill Avenue, Partick.
1911. Humphreys, G. W., M.A., 40 Derby Street.

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Year of Election.

1908. Hunter, George, M.I.M.E., Mining Department, Technical College, Montrose Street, Glasgow.

1901. Hunter, William, Rosemount, Ledard Road, Langside.

1903. Hurll, Mark, Redholm, Temple.

1911.*Innes, Peter, 5 Ibrox Place, Paisley Road West.

1890. Johnston, Ronald H., C.E., 190 West George Street.

1901. Kemp, William, c/o Mrs. Brown, 1 Doune Quadrant, Kelvinside North.

1889.*Ker, William, 1 High Windsor Terrace, Glasgow.

1908. Kerr, Andrew C., c/o Carron Co., 125 Buchanan Street.

1908. Kerr, David, Lynnewood, 140 Bo'ness Road, Grangemouth.

1890. Kidston, Robert, LL.D., F.R.S., 12 Clarendon Place, Stirling.

1882. King, Hugh B., Solicitor, Kilwinning.

1882. King, Robert C., Solicitor, Ledcameroch, Kilwinning.

1908.*Knight, James, M.A., D.Sc., F.R.S.E., F.G.S., F.C.S., St. James's Public School, Calton.

1883. Laird, Andrew, C.E., 5 Northbank Terrace, Kelvinside.

1907. Laird, Arch. J., M.I.M.E., F.R.G.S., Kelvinbank, Smith Street, Hillhead.

1911. Lawson, Tullis, 141 Stanmore Road, Mount Florida.

1908. Leitch, P. Arthur, Engineer's Office, District of Middle Ward, Hamilton.

1899. Lyle, William, 7 Beechwood Terrace, Shettleston.

1910. M'Callum, Gavin W., 65 Main Street, Pollokshaws.

1896. M'Cowan, Donald, Dundashill House, Port-Dundas, Glasgow.

1889. M'Creath, George W., M.E., 208 St. Vincent Street, Glasgow.

1904. M'Creath, William, C.E., M.I.M.E., 208 St. Vincent Street, Glasgow.

1901. M'Culloch, Andrew, 11 West Regent Street, Glasgow.

1901. M'Culloch, Rev. J. D., Mearns Street Congregational Church, 9 Wellington Street, Greenock.

1884. M'Donald, A. B., C.E., 64 Cochrane Street, Glasgow.

1908. M'Donald, David P., M.A., B.Sc., S. A. School of Mines and Technology, Johannesburg.

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Year of Election.

1907. Macdougal, John, 37 Broomhill Drive, Partick.
1898. M'Gavin, Alex., 10 Lothian Gardens, Kelvinside North.
1894.*M'Gilvray, Robert A., 6 Newton Terrace, Charing Cross.
1867. M'Glashan, John, 114 Candleriggs, Glasgow.
1910. M'Gregor, Murray, M.A., B.Sc., 156 Stanmore Road.
1904. Macintyre, Arch., F.S.A.A., 60 Cadzow Street, Hamilton.
1898. M'Kellar, John, Nooklands, Dumbarton.
1894. Mackie, John, M.E., Crofthead Cottage, Neilston.
1877. Maclay, Bailie Wm., F.G.S., Thornwood Hall, Langside.
1894. Maclay, James, M.A., LL.B., Ferndean, Garelochhead.
1903. M'Lean, Alex., 466 St. George's Road, Glasgow.
1895. Macnair, Peter, F.R.S.E., F.G.S., Art Galleries and Museum, Kelvingrove.
1897.*M'Neil, Charles, 1 University Gardens.
1910. MacPhee, Miss Margt. F., Broompark, Helensburgh.
1883. M'Whirr, John, J.P., 3 St. John's Road, Cathcart.
1887. Main, John, F.G.S., 24 Marlborough Avenue, Partick.
1900. Mann, Andrew C., 30 Lansdowne Crescent, Glasgow.
1874. Mann, Ludovic M'Lellan, F.S.A.(Scot.), 144 St. Vincent Street, Glasgow.
1909. Mathieson, Rev. A. Scott, 7 Lynedoch Crescent.
1902. Menzies, James R., 72 Lauderdale Gardens, Hyndland.
1881. Mitchell, G. A., 5 West Regent Street, Glasgow.
1899. Mitchell, James M., Bannockburn House, Bannockburn.
1908. Monie, Matthew M., M.A., B.Sc., Agricultural College, 6 Blythswood Square.
1904. Moore, Quintin, 101 Armadale Street, Dennistoun.
1877. Moore, Robert T., D.Sc., C.E., 142 St. Vincent Street, Glasgow.
1908.*Morrison, James, 87 East Princes Street, Helensburgh.
1889. Motherwell, A. B., Rosemount, Airdrie.
1900.*Muirhead, John, 13 St. John's Drive, Pollokshields.
1898. Munro, Alexander, 63 Lauderdale Gardens, Hyndland.
1909. Munro, John, 95 Waterloo Street.
1894.*Murdoch, Robert, 91 Maxwell Road, Pollokshields.
1907.*Murdoch, J. A. W., Capelrig, Dunblane.
1870.*Murray, David, LL.D., 169 West George Street, Glasgow.
1907. Murray, Andrew G., c/o Brownlie, Watson & Beckett, 225 West George Street.

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Year of Election.

1907. Neilson, Miss Agnes T., 41 West Cumberland Street, Glasgow.
1891. Neilson, James, Alma Boiler Works, Crownpoint Road.
1894. Neilson, James, 116 Bishop Street, Port-Dundas.
1907. Nicol, J. Hall, Builder and Contractor, Hamilton.
1906. Nicolson, David G., Schoolhouse, Neilston.
1898. Nimmo, David, 17 Duke Street, Hamilton.

1869.*Orr, John, 12 Newhall Terrace, Glasgow.

1905. Paisley, John, Jeweller, 25 Gordon Street, Glasgow.
1905. Paton, R. Knox, c/o Evançion Gold Mining Co., Ltd., Verres, Val d'Aosta, North Italy.
1891. Pollok, Arthur, Kirkland, Bonhill, Dunbartonshire.
1910. Preston, Frank A. B., 16 Waverley Park, Shawlands.
1910. Priestly, H., 8 Glenview, Paisley.

1873. Rankine, David, C.E., 238 West George Street, Glasgow.
1880. Reid, James A., LL.D., 172 St. Vincent Street.
1874. Renwick, John, 47 Oswald Street, Glasgow.
1902. Reoch, James W., 22 Montgomerie Street, Kelvinside.
1911. Ritchie, Rev. A., M.A., 8 Queen Margaret Crescent, Hillhead.
1911. Roberts, J. G., Trees Cottage, Barrhead.
1875.*Rottenburg, Paul, LL.D., Holmhurst, Dowanhill Gardens, Glasgow.
1904. Rutherford, James, M.E., 34 Granby Terrace, Glasgow.

1898. Scott, Colonel, Bellside, Cleland.
1897. Shanks, Arch., Mount Pleasant, Dalry.
1893.*Sharp, John Grant, 127 Great Hamilton Street, Glasgow.
1908. Sharp, R. S., 275 Nithsdale Road, Dumbreck.
1910. Shute, Arthur E., 4 Holyrood Crescent West.
1889. Simpson, Rev. Alex., B.A., B.Sc., F.G.S., 28 Myrtle Park, Crosshill.
1888. Sinclair, Thomas, 206 New Dalmarnock Road, Glasgow.
1887. Sinclair, William, 47 Oswald Street, Glasgow.
1889. Sloan, Samuel, M.D., 5 Somerset Place, Sauchiehall Street, Glasgow.
1911. Smellie, Wm. R., M.A., B.Sc., Mayfield Villa, Mossend.

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Year of Election.

1908. Smith, Duncan, Laurelbank, Arkleston Road, Paisley.
1887.*Somerville, Rev. James E., B.D., Castellar, Crieff.
1871.*Sommerville, Joseph, 40 Montgomerie Street, Kelvinside North.
1902. Spencer, James S, 14 University Gardens.
1896. Stark, James, 13 Princes Gardens, Partick.
1881. Steel, James, 37 Prince Edward Street, Crosshill.
1910. Stevenson, Wm., jun., 13 Murray Place, S.S.
1906. Stewart, Robert D., Belinda Cottage, Shettleston.
1878. Stewart, Thomas, St. George's Chambers, Cape Town, South Africa.
1911. Stewart, W. Wylie, 312 West Princes Street.
1891. Stirling, David, 10 Cook Street, Glasgow.
1902. Sykes, William, 24 Hamilton Park Terrace, Hillhead.

1909. Tervet, G. Macleod, 9 Whitehaugh Drive, Paisley.
1897. Thomson, Henry, 10 Princes Square, Strathbungo.
1906. Tyrrell, G. W., A.R.C.Sc., F.G.S., Geological Department, Glasgow University.

1907. Waddell, A. W., M.E., 4 Eton Terrace, Hillhead.
1910. Watson, George C., c/o Kennedy, 478 St. Vincent Street.
1901. Wight, E. Hall, 150 Hope Street, Glasgow.
1909. Williamson, James, A.M.I.C.E., 160 Hope Street.
1909. Wise, Thomas, Ailsa Cottage, Scott Street, Hamilton.
1881. Wotherspoon, David, 982 Argyle Street, Glasgow.
1910. Wright, James, jun., 36 Douglas Street, Kirkcaldy.
1911. Wyllie, B. K. N., M A., Students' Settlement, 10 Possil Rd.

1902. Young, Arch. A., 2 Parkgrove Terrace West, Glasgow.

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THE GEOLOGICAL SOCIETY OF GLASGOW.

INSTITUTED 1858.

CONSTITUTION as Amended,

SESSION 1905-06.

I.—NAME.

The Society shall be called "THE GEOLOGICAL SOCIETY OF GLASGOW."

II.—OBJECTS.

The objects of the Society shall be—

I. To unite, in permanent working association, the students and friends of Geological Science in Glasgow and surrounding districts.

II. The advancement of that science, by means of periodical Meetings for its study; the reading and discussion of Papers on subjects illustrative of Geology or its allied Sciences; the exhibition and description of specimens; the delivery of Lectures; and by Excursions.

III. The formation of a Library chiefly relating to Geology, Palæontology, Petrography, and Mineralogy.

IV. The publication of the Society's *Transactions* and *Proceedings*.

III.—MEMBERS.

The Society shall consist of Ordinary, Associate, Honorary, Honorary Associate, and Corresponding Members.

IV.—ORDINARY AND ASSOCIATE MEMBERS.

All candidates for Membership shall be proposed on the recommendation of two Members, and their names announced in the circular calling an Ordinary or Special Meeting, at

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which Meeting their election shall be put to the vote from the chair. If not unanimous, the vote shall be taken by ballot.

The Annual Subscription shall be—for Ordinary Members—Gentlemen, 10s., and Ladies, 7s. 6d., payable upon election, and thereafter at the first Ordinary Meeting of each Session in October.

A single payment of Five Guineas shall entitle any Member elected as aforesaid to be entered as a Life Member.

Students attending Geological Classes shall be eligible for admission as Associate Members for the current Session at a Subscription of 2s. 6d., with the right of attending all Meetings and Excursions, and of using the Library, but not of voting, nor of receiving the *Transactions*.

Members whose Subscriptions are in arrears shall not be entitled to vote, nor to use the Library, nor to receive the *Transactions*.

Members shall be held liable for their Annual Subscriptions until they have given written notice of their resignation.

V.—HONORARY MEMBERS, HONORARY ASSOCIATES, AND CORRESPONDING MEMBERS.

The Ordinary Members shall have power to elect—on the motion of two of their number—Honorary Members, Honorary Associates, and Corresponding Members, at any Meeting, provided that notice of the said motion has been given at a previous Meeting and received the sanction of a majority of the whole Council. The votes of two-thirds of the Members present and voting shall be requisite for the election of all such Members.

(1.) Persons distinguished for their attainments in Geology or the allied Sciences shall be eligible as Honorary Members. These shall be entitled to the same privileges as Ordinary Members.

(2.) Persons resident in Glasgow or neighbourhood, who may have benefited the Society by services rendered, by donations of books, or by the contribution of original communications, shall be eligible as Honorary Associates.

(3.) Friends and Students of Geological Science resident at a distance from Glasgow, who may be willing to forward information or communications to the Society, shall be eligible as Corresponding Members.

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Honorary Associates and Corresponding Members shall be entitled to attend the Meetings, Lectures, and Excursions, but shall have no vote in the management of its affairs, nor be entitled to receive copies of the *Transactions*, except at the discretion of the Council.

VI.—OFFICE-BEARERS.

The business of the Society shall be conducted by a Council of twenty-one, consisting of a President, three Vice-Presidents, two Secretaries, a Treasurer, a Librarian, an Editor of *Transactions*, and twelve Councillors.

The election of Office-Bearers shall take place by ballot, at the Annual General Meeting. The names of those proposed to fill the various offices, together with their proposers and seconders, shall be sent in to the Secretaries at least eight days before the Annual General Meeting, and submitted to a Meeting of Council, and printed in the Circular calling that Meeting.

They shall take office for three years. The President, Secretaries, Treasurer, Librarian, and the Editor of *Transactions* shall be eligible for re-election. The senior Vice-President and the four senior Councillors shall not be eligible for re-election to such offices as those they retire from in rotation until they have remained one year out of office.

VII.—CHAIRMAN.

In the absence of the President, or by arrangement with him, one of the Vice-Presidents, or, failing them, a Member of Council, shall preside. The Chairman shall have a deliberative and a casting vote.

VIII.—SECRETARIES.

The Secretaries shall act both for the Society and the Council, and shall give due intimation of all Meetings of the Society and the Council, record the proceedings of the Meetings in the Minute-Books, prepare abstracts thereof for publication in the newspapers, keep a register of the names and addresses of Members and Associates, and conduct the general correspondence of the Society. They shall be *ex officio* members of all Sub-Committees.

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IX.—TREASURER.

The Treasurer shall receive and pay (as authorised by the Council, or by any General or Special Meeting of the Society) all moneys connected with the Society, and shall keep a regular account of the same, which account shall be balanced as on the 30th September of each year, audited by two Members, who shall not be Members of Council at the time, and submitted to the Annual Business Meeting in November.

X.—LIBRARIAN.

The Librarian shall have charge of the Library and all other property belonging to the Society, and shall arrange and keep a Catalogue thereof.

The *Transactions* shall be exchanged with such Societies and Geological Authors at home and abroad as may be approved of by the Council. The Librarian shall have charge of such exchanges, and shall keep a correct list of the same. Members shall have access to the Library on the nights of Meeting, and at such other times as the Council shall arrange.

XI.—EDITOR OF "TRANSACTIONS."

The Editor shall attend to the preparation of the material for the Society's *Transactions* and *Proceedings*. A Publishing Committee, of which the Editor shall be Convener, shall be appointed annually by the Council, and shall decide as to all papers or abstracts of papers to be printed, and the illustrations to accompany them.

XII.—COUNCIL.

The Council shall meet as often as may be requisite for the transaction of the Society's business, and five shall form a quorum. They may appoint Sub-Committees for the management of special business. They shall make arrangements for the Winter Session, and also for the Excursions. They shall prepare a report of the affairs of the Society for the past year to be submitted to the Annual General Meeting.

Any vacancy occurring during the year may be filled up by the Council; but such appointments shall only be for the unexpired portion of the previous occupant's term of office. Members so elected shall, however, be eligible for re-election if their period of such office has not extended beyond two years.

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XIII.—MEETINGS.

Ordinary Meetings of the Society shall be held once a month during the Session, commencing on the second Thursday evening in October, at eight o'clock, but more frequently if the Council should deem it advisable. At these Meetings the order of business shall be as follows:—The Minutes of the previous Meeting shall be read and confirmed; the vote taken on any candidates whose names have been duly proposed for Membership; the names of those applying for Membership submitted; specimens of geological interest exhibited and remarked upon; papers read and discussed, and any other competent business disposed of. The second Meeting of each Session shall be the Annual General Business Meeting, at which one of the Secretaries shall read the report of the Council for the past year; the Treasurer shall submit the Financial Statement; the Librarian shall report on the state of the Library, and the Editor of *Transactions* report on the progress of the Publications of the Society. The election of Office-Bearers shall then be proceeded with, and the ordinary business follow.

Special Meetings.

The Council shall be empowered to call, at any time when necessary, a Special Meeting of the Society, and shall be bound to do so on the written requisition of ten Members, specifying the business to be submitted thereto.

At all Meetings the resolutions of a majority of those present and voting—with the exceptions stated in Laws V. and XVI.—shall be binding.

XIV.—VESTING OF PROPERTY.

The property of the Society shall belong solely to the Ordinary Members, and shall be vested for their behoof in the Council for the time being. The Council shall have the management of the property, and power to sell or otherwise dispose of any duplicate Books or copies of the *Transactions* at prices they may arrange. Any other property which they may consider unnecessary to retain shall only be disposed of with the consent of a majority of the Ordinary Members present at a Meeting of the Society, and notice shall be given in the Circular calling the Meeting of the intention to ask such consent.

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XV.—APPLICATION OF FUNDS.

The Annual Subscriptions, and the annual revenue from Life-Membership Subscriptions, shall be devoted to the general work of the Society, special attention being given to the printing and illustrating of the Society's *Transactions*, of which all Ordinary Members shall be entitled to receive a copy of each Part published during their term of membership.

Should the Subscriptions at any time be insufficient for this purpose, the Council shall have power to fix such a charge for each Part of the *Transactions* as may be required to make up the deficiency.

Papers printed in the *Transactions* shall entitle the Authors to receive thirty copies of their papers free.

Sums may be voted from time to time by the Council for the Library and for other purposes out of any funds there may be on hand, but not exceeding Two Pounds in value without the sanction of a General Meeting.

The capital from the Life-Membership Subscriptions shall be retained as a separate Fund for the re-publication of such Memoirs or Parts of the *Transactions* as may become out of print, and be still in demand; for special Publications or of Exhibitions in connection with the visits of other learned Societies; and generally for such exceptional purposes as are not provided for by the Annual Subscriptions.

The Council shall obtain the sanction of a Meeting of the Society before applying any portion of this Fund in such way.

XVI.—ALTERATION OF THE CONSTITUTION.

No alteration shall be made in the Constitution of the Society except at a Meeting of which special intimation has been given by Circular issued for that purpose. Notice of any proposed alteration shall be made at the Meeting preceding, and shall not be adopted unless agreed to by two-thirds of the Members present and voting.

XVII.

Any contingency not provided for in the foregoing Rules shall be submitted to the Council, and their decision shall be final and binding on all concerned.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. VIII.—The Polmont Kame and on the Classification of Scottish Kames. By J. W. Gregory, D.Sc., F.R.S., University, Glasgow.

[Read 9th May, 1912.]

1. Polmont Kame—its course and structure.
2. The Neighbouring Drumlins.
3. The Origin of the Kame.
4. The Relations of Kames and Eskers.
5. Other Varieties of Scottish Kames.
6. The Unity of the Glaciation at Polmont.
7. Post-Glacial Denudation at Polmont and its Duration.

Travellers from Glasgow to Edinburgh by the North British Railway may observe at Polmont Station a deep cutting in coarse gravel containing some large boulders; and on both sides of that station, to the north of the railway, they may see a narrow, sinuous ridge of gravel, which runs beside the line from Redding to Laurence Park. This well-defined ridge, when seen from the train, strikingly resembles some of the typical eskers or åsar (osar) of Sweden; and until I had the opportunity of visiting it, I regarded it as the most esker-like formation I had seen in the south of Scotland.

There are occasional brief references to this gravel ridge in Scottish glacial literature. It is twice referred to in Sir Archi-

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bald Geikie's "Scenery of Scotland," and he calls it "an admirable example of a kame."[1] Mr. Peach, in the "Memoirs of the Geological Survey of Scotland, Explanation of Sheet 31, 1879," p. 51, also refers to it as a kame. He says—"One ridge deserved special mention, from the fact that it runs as a conspicuous feature parallel with the Edinburgh and Glasgow Railway from Redding to the borders of Linlithgowshire, a distance of 3 to 4 miles. This is not its whole length, however, for it passes westward from Redding by Callander Park, where it is breached, to the town of Falkirk, which is built on it, and it runs eastward across the valley of the Avon, which has cut across it. Its entire length cannot be less than 8 miles."

A sketch map of its general course and a figure of a cross-section have been given by D. Milne Home.[2] He also calls it a kame. His section represents it as unstratified, though he refers to it as being in places "more or less stratified." He explained it[3] as an old submarine bank.

1. The Polmont Kame—Its Course and Structure.

This kame is best defined for a length of about 3 miles from Callendar Park, near Falkirk, to Laurence Park; but it can be traced further east, for another mile and a half, to the south of Bo'ness High Junction Station, on the western bank of the Avon valley.

The kame can be examined most conveniently near Polmont Station, where it is exposed on the northern bank of the railway cutting. Immediately north of the station the kame is cut through by the main road, and the kame then bends abruptly to the west. It is well seen for a length of two-thirds of a mile east and west of Meadowbank, to the west of which the northern side is in places 20 to 25 feet high, and the slope is 25°. The kame contracts to about 30 feet in width, exclusive of the gradual slope at the base, at a place where it is only 10 feet

[1] A. Geikie. "Scenery of Scotland," 3rd edit., 1901, pp. 466, 402.

[2] D. Milne Home. "The Estuary of the Forth and adjoining Districts viewed Geologically." Edinburgh, 1871, fig. 14 and 16, opp. p. 32; also pp. 32, 35, 36.

[3] D. Milne Home. *Ibid.* p. 36.

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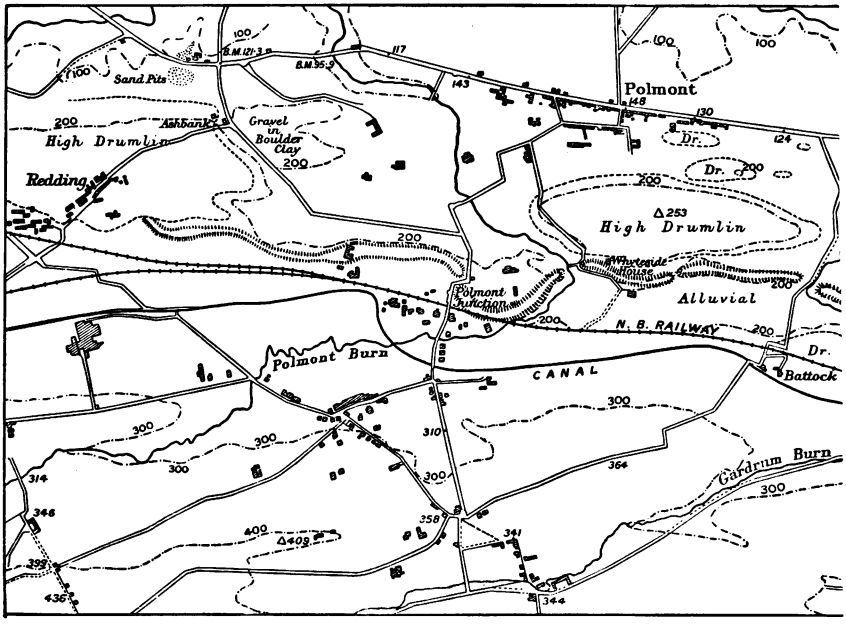

Sand - Redeposited from Boulder Clay
Kame
Approximate border of some conspicuous Drumlins (Dr.)

MAP OF THE GLACIEL
NEAR POLMO

Fig. 1.

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high above the ground to the north. It then rises and widens at a bend where gravel has been dug from it. Some heaps of boulders beside the old pit are probably partly from the kame and partly from the adjacent fields, as some are plough marked. The margin of the kame then becomes somewhat indefinite on the northern side, though it is still steep and well defined to the south. On its northern side it rests on and against some rounded hummocks of boulder clay. Near the farm of Whole Quarter, the kame bends to the north and gradually disappears, as the kame material was here probably deposited as a thin layer of wash on the southern slopes of the hills of boulder clay. The steep southern side of these hills skirts the northern edge of the village of Redding. The kame reappears as a well-defined ridge to the west of Croft Cottage. It is cut through by Westquarter Burn, bends to the north-west, and, beyond the grounds of Westquarter House, forms a conspicuous ridge a third of a mile south of Laurieston. A gravel pit has been opened in it and shows its unstratified nature. The kame then crosses the road and the railway, and is lost behind the high wall of Callander Park. I have walked along the wall on the western side of the park, from 1 to 1½ miles to the west, but saw no sign of the re-emergence of the kame into open land. Dr. Peach remarks that Falkirk has been built on the kame; so that possibly, inside the park, it curves to the north; and it may form the base of the ridge used by the Roman Wall which runs parallel to the main Falkirk road.[4]

In the part of its course between Polmont and Falkirk the kame slowly descends in level westward, from 220 feet at Polmont Station, to 160 feet where it crosses the Redding road south of Laurieston. Falkirk is at the level of about 100 feet.

Returning to Polmont Station and following the kame eastward, it is seen to curve northward along the left bank of Polmont Burn, which cuts through it west of Whyteside House. It then follows a slightly sinuous course eastward, until it reaches the golf course south of the farmhouse of Gilston. Here it subdivides; a low northern branch continues eastward across the golf course—where the nature of the material was seen in

[4] A map by the author in *Geogr. Jour.*, vol. xl., August, 1912, p. 171, is reproduced as Fig. 1 by the courtesy of the Geographical Society.

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a post hole—and then bends north-eastward to Sighthill. The main branch bends a little southward, until it is north of Nicolton; there it turns sharply to the south-east and rises as it skirts the high ground south of Laurence Park. It here disappears for a short space as it rests against the drumlins of boulder clay. It soon, however, again becomes distinct, and its southern lobe is cut through by the railway. East of the bridge over the railway at the north-western corner of Almond Wood, the kame extends as a well-developed ridge on the northern side of the railway, past Almond Wood, and then crosses the line again, its eastern edge being just by the signal post 500 yards west of Bo'ness High Junction Station. It forms a line of gravel hills to the south of the railway; it is cut through by the Slamannan Junction Railway, and then disappears on the western slopes of the Avon valley.

Throughout its course east of Polmont its character is that of a well-defined, sinuous ridge, of which the southern face is generally the steeper. The ridge is sometimes, however, symmetrical in section. Its southern slope generally ends on a level tract of boulder clay, which may also be seen on its northern side. But in places the kame rests against the drumlins on the northern side of it, and is then not developed as a distinct ridge.

The kame has been breached in many places, and the gaps are used by the roads and streams. The general width of the kame is from 10 to 40 yards wide at the base, and its height above the adjacent ground varies from 10 to 50 feet. The sides have slopes of from 15° to 25°.

The Structure of the Kame.—The largest section is at Polmont Railway Station, where the kame consists of coarse gravel containing boulders but not much sand. The section is obscured by the slipping of the gravel. The bedding is ill defined, though it is indicated by irregular bands of coarser material, but there is no conspicuous false bedding. The gravel pit east of Whyteside House gives a useful section along and within the kame. The material is irregularly mixed; and there are no signs of either the longitudinal seasonal stratification of the typical Swedish eskers, or of false bedding.

The most striking feature in the structure of the kame is the

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lack of the well-marked stratification and false bedding of the typical kames and eskers. Definite stratification is exceptional.

The whole of the kame material is water-worn gravel, but the pebbles are well rounded. The great majority retain the form of the stones in boulder clay, but they have been so water washed that the glacial striæ have been destroyed and the edges blunted.

The kame material includes boulders of Carboniferous sandstones and limestones, and of various basalts; also pebbles of the schistose grits and schists of the Highland Series, and of the igneous rocks intrusive into them. A high proportion of the smaller pebbles often consists of vein quartz. In some places the kame contains well-rounded quartzites from the Old Red Sandstone conglomerates, and pebbles of Old Red Sandstone porphyrites. Occasionally, as along the ridge west of Gilston, the small pebbles are so crowded that the kame consists of a fine-grained pebble bed, composed of pebbles from $\frac{1}{2}$ inch to 2 inches in diameter. In an adjacent place the kame consists of fine gravel, and occasionally, as due west of Laurence Park House, it contains patches of sandy material.

Boulders are fairly numerous in the kame, and sometimes occur on the very top of it. Thus a little to the west of the road which cuts through it to the south-west of Gilston, there is a boulder of porphyritic basalt, 20 inches by 12 inches by 10 inches in size, and on the northern slope of the kame lies a boulder of white Carboniferous sandstone measuring 20 inches by 16 inches by 10 inches. The section at the deep railway cutting south of Laurence Park is overgrown, but there are layers with large water-worn boulders, interstratified with bands of water-worn, subangular, small pebbles, which are from a quarter to half an inch in diameter.

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The composition of the gravels may be illustrated by the following analyses:—

	Gravel Pit South of Laurieston.	Gravel Pit east of Whyteside House, near Polmont.[9]		
		36 boulders and pebbles over 3 inches long, from an area of 10 feet square.	Pebbles under 3 inches long from the same position as the boulders	
			South side of the kame	North side of the kame
	Per cent.	Per cent.	Per cent.	Per cent.
Carboniferous Sandstones,[5]	27	33½	27	25[6]
Basalts—Fine grained,	24	22	27	
Porphyritic,	6·5	16½	3	
Vesicular,	—	5½	1	48
Various, including quartz-dolerite,	5	8½	6	
Porphyrites from the Old Red Sandstone,	5	—	—	—
Quartzite Pebbles from the Old Red Sandstones,	3	—	4	10
Granular Highland Quartzites,	8·5	5½	—	
Schistose Grits,		5½	19	13[8]
Other Schists from the Southern Highlands,[7]		—	2	—
Felsites from the Southern Highlands,		—	3	3
Cherts and Cherty Shales from the Balmaha Series,	1	—	1	1
Vein Quartz,	19	2¾	7	—
	99	99½	100	100

The most significant feature of these lists is the northern origin of the material.

[5] Including a few probably from the Old Red Sandstones.

[6] Includes four pebbles of cementstone and some of tuff.

[7] Including mica-schist and hornblende-schist.

[8] Includes one of schistose conglomerate.

[9] The analyses at the Whyteside Gravel Pit were made during an Excursion of the Glasgow University Geological Society.

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Sections north and south through the kame are given on Fig. 2.

2. The Neighbouring Drumlins.

The boulder clay covers most of the country beside the kame, and rises into a series of drumlins, of which the majority are on its northern side.

Sections in the unweathered boulder clay are scarce. Two small exposures occur on the Gardrum Burn, 630 yards along the road going west from Bethankie Bridge; and they show that the material, when unweathered, is a typical blue, stiff, boulder clay. In most of the district it has weathered to a loose loamy soil, as the rain has washed away much of the clay. Boulders are not common in the fields, as they have been removed during cultivation. They are still abundant on the beds of the streams, and are found in heaps along the sides of the fields.

Many of the stones are glacially striated, and by this character the kame material can be easily separated from the soils above the boulder clay. The boulder clay contains a large proportion of rocks from districts to the north; it includes various Highland schists, blocks of vein quartz from those rocks, pebbles of quartzite derived from the Old Red Sandstone conglomerates, and some specimens of the porphyrites from the Old Red Sandstone. There are abundant fragments of various basalts and Carboniferous sedimentary rocks. The boulder clay occasionally contains pockets of sand, which give rise to sandy patches on the fields.

The boulder clay usually forms bare, rounded, mound-like drumlins, which are often elliptical in shape. They form the highest ground north of the kame; they rise to 253 feet above sea level, just east of Polmont, and to 270 feet north of the Redding Explosive Works. Between Avon House and the North British Railway to the east of Laurence Park, the boulder clay rises to a tract of ground, a mile in width from north to south, and mostly above the level of 200 feet. The kame at Laurence Park is banked against the southern edge of these drumlins; but further east the kame bends to the south and again forms a distinct ridge, while the drumlins of boulder clay descend in parallel whaleback-like hills, which sink gradually into the more level land beside the Avon.

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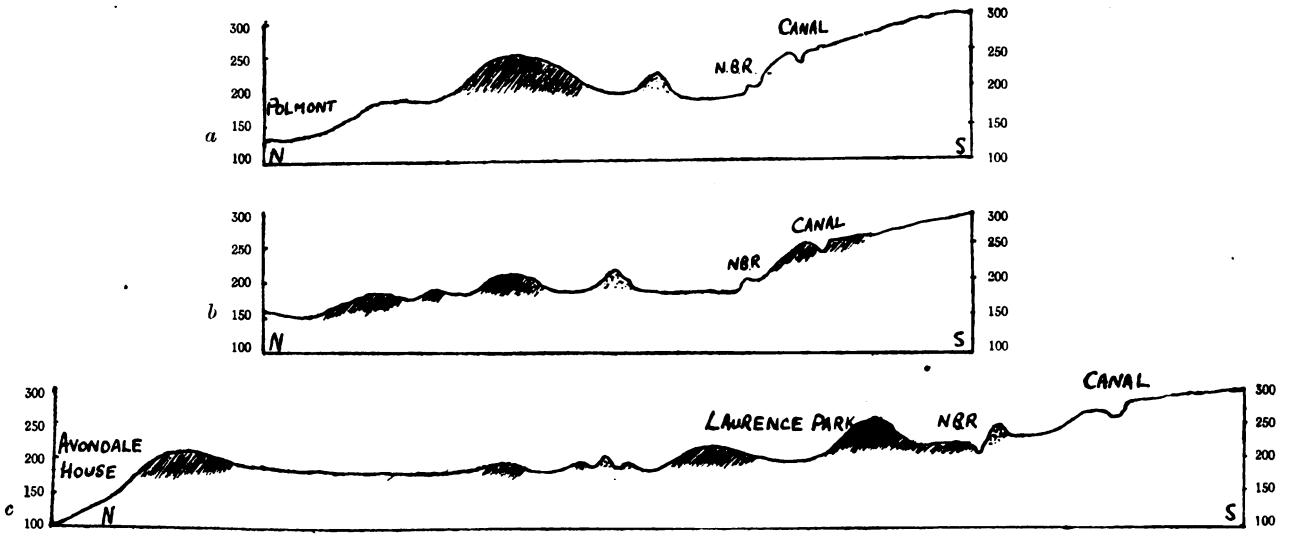

FIG. 2.—Sections across the Polmont Kame.

a Through Polmont and the 253-ft. Drumlin.
b Through the Kame west of Gilston.
c Through the branches of the Kame near Laurence Park.

Kame.

Drumlins of Boulder Clay.

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Even on the low ground the boulder clay usually has an undulating surface with a loamy soil. The tops of some of the drumlins are covered with sand, as in the hill, 200 feet high, in the wood south of Avondale House, and in the hill on the western side of the road to Polmont Hill, to the east of Gilston Burn. The sandy nature of these hill tops may be due to the clay having been washed down the hillside, though the abundance of pebbles of vein quartz, and Highland schist suggest that the material may have come from interbedded layers of glacial gravel. Such beds occur occasionally, as in the "Old Quarry" marked on the 6-inch map (Stirlingshire, sheet xxxi., N.W.) opposite Ashbank, a little more than half a mile north-west of Polmont Station. These beds have been worked for sand.

The chief sand deposits of the district are, however, at the northern foot of the drumlins. They are well shown in the pits on both sides of the road from Polmont to Falkirk, just west of Polmont Cottage, at the level of a little below the 100-foot contour. The pit in the plantation on the southern side of the road gives the better section; the sand is very false-bedded, and has some layers of clay, two bands of gravel interbedded in the sand, and some lenticles and layers full of coal fragments. The prevalent falsebedding indicates that the material was deposited by water flowing from south to north. These sand beds are clearly post-glacial formations, and their materials have been derived mainly from the boulder clay.

3. The Origin of the Kame.

The oldest glacial deposit in the locality is the sheet of boulder clay, which has been spread as a mantle over the hills to the south of the Forth valley. Though I know of no section where the base of the kame is exposed, it clearly rests on the boulder clay and was deposited after the formation of the boulder clay to the south of it. But it was probably formed at the same time as the boulder clay of the drumlins to the north.

Both the kame and the boulder clay contain so high a proportion of northern rocks that it is natural to refer these

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deposits to the action of a glacier which flowed southward from the Southern Highlands. This glacier crossed the Old Red Sandstone and collected from it fragments of porphyrite and many pebbles of quartzite. The glacier probably came from the neighbourhood of Callander and Ben Ledi, passed down the Forth valley around the western end of the Ochil Hills and overflowed the estuary of the Forth. During its retreat the edge of this glacier must have been for some time stationary nearly along the line of the kame. The ice had, however, extended beyond the kame, for the boulder clay has identical characters on both sides of it.

The sinuous form of the kame suggests at first that the ridge may be a true esker. The evidence, however, seems clear that it is not a river deposit. The evidence against that mode of formation is as follows:—

1. The material is different in shape from that of fluviatile or fluvioglacial gravels; the great majority of the pebbles retain the angular forms of the stones in boulder clay; the well-rounded pebbles of river gravels are comparatively rare and consist of soft rocks, excepting in the cases of pebbles which have been derived from older conglomerates. The stones in the kame are rather water washed than rolled or worn. Occasional thin slabs of Carboniferous sandstone have the edges abraded but the faces unworn; and they cannot have travelled far in water, in which they would soon have been broken up.

2. The material is either unstratified or only obscurely stratified, and contains no interbedded layers of sand, though it occurs in pockets.

3. The boulders, which in places are not unfrequent, are so water washed that their striæ have been removed; but their projecting knobs and corners have only been smoothed and not worn away. The boulders have not been rolled far in water.

4. The level of the base of the kame fluctuates in height, for it rises from about 100 feet at Falkirk (*vide* Dr. Peach) to 150 feet at Laurieston, and to 240 feet at Polmont. It then falls again to 200 feet near Gilston, and rises again to 220 feet by the railway south of Laurence Park, and falls again to 200 feet at its eastern end near Bo'ness High Junction Station. Such variations

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in level would be quite natural on the edge of a glacier resting against the undulating side of a valley. But they could only occur in a sub-glacial river if the water were confined in a water-tight channel, as in a pipe.

According to Shaler,[10] "Unlike ordinary rivers, the streams beneath the ice flow up hill and down as they follow the devious outline with which the sheet of frozen water rests upon the surface." This switchback course of a sub-glacial river could only happen when, as Shaler remarks, the water is flowing with great violence, and it could then hardly deposit sand and unrolled pebbles in its channel. The material in the Polmont kame was obviously not deposited by violent streams of water; its undulations in level therefore show that it cannot have been formed by a sub-glacial river, and the absence of longitudinal bedding shows that it was not formed at a receding river mouth. The sub-glacial drainage under this glacier would, moreover, have tended to flow down the slope northward into the estuary of the Forth.

5. Further, the general flow of the drainage from the glacier was doubtless from west to east, and the course of the branch from the kame near Gilston does not resemble that of a tributary from the west; it diverges at a low angle, and continues eastward.

6. The kame disappears in places, as at Redding and Laurence Park, and its absence is more easily explained by non-deposition than by subsequent removal. In these places the gravel was probably deposited as a layer of wash on the southern slopes of the drumlins, and not as an independent ridge. The kame material is never thus spread out over the slopes of the boulder clay to the south of the kame. It happens only on the drumlins to the north. The ice from which the kame material was derived was therefore always on the northern side of the kame.

The kame was therefore not a river deposit, nor can it be regarded as a moraine, although it was deposited along the margin of a melting glacier. As the ice melted, it no doubt deposited its intra-glacial material *in situ* as boulder clay.

[10] N. S. Shaler. "The Geological History of Harbors." Thirteenth Annual Report U.S. Geological Survey, part ii., 1893, p. 117.

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The water formed by ablation appears to have poured down the sloping margin of the glacier, and rolled along with it many stones and occasional boulders. These materials collected as a bank along the margin of the glacier, but they did not form a lateral moraine, as they were not deposited directly by the melted ice, but by floods of water. The glacier at this period of its retreat does not seem to have formed marginal moraines. Their absence may be explained by the fact that the ice was far from any hills that could have shed their débris upon it. The upper layers of the ice were probably free from either intra-glacial or supra-glacial material. Probably all the stones carried by the glacier to Polmont were within the ice, and were therefore nearly all glaciated and rendered sub-angular. Most of the included stones were facetted and scratched. The ice therefore had no supply of coarse sub-angular material, such as is carried in the lateral moraines of mountain glaciers.

The kame is not morainic, because its material was all deposited by water. It is not a fluvioglacial deposit, for it was formed by the mere irregular wash of water down an ice slope, and not by streams. It is therefore more of the nature of a bank of rain-wash than a fluviatile deposit. It is colluvial, to use Merrill's term, rather than alluvial. But, as some term is needed for a glacial colluvial deposit, such a ridge of gravel may be conveniently described as glacieluvial, a term kindly suggested by Professor Phillimore.

Whether this glacieluvial ridge is to be regarded as a kame or an esker depends on the interpretation of those terms.

4. The Relations of Kames and Eskers.

According to the majority of authors, the terms "kame" and "esker" are synonymous. "Kame" is generally represented as the Scottish term for the glacial formations, which are known as åsar in Sweden and eskers in Ireland.

The authorities are unanimous that eskers are fluvioglacial formations, and the term should be limited to the formations of glacial rivers. These rivers were subglacial, according to some authorities, and supra-glacial according to others; but

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that controversy has ceased, with the growing adoption of the view, proposed by O. H. Hershey[11] from his studies in Illinois, that eskers are formed where the rivers emerged from the ice. The process had been clearly described by Russell for the streams emerging from beneath the Malaspina Glacier, Alaska.[12] As the glacier front receded the deposition of the esker gravels followed it, and the esker was laid down as a band along the course of the river. Baron de Geer has confirmed this explanation for the Swedish eskers by showing that they have a seasonal banding, due to the varying volume of the river during the year.

Eskers are therefore river deposits, as is clearly shown by the maps of the eskers of Sweden, New England, and Ireland.

The effort has been made to limit the term "kames" to fluvioglacial mounds, and eskers to fluvioglacial ridges,[13] but the proposal by Professor Chamberlin to limit kames to the marginal deposits laid down along the edge of the ice, and eskers to the river deposits more or less at right angles to the edge of the glacier, seems a more satisfactory basis of separation.[14]

The Polmont ridge, as a marginal deposit, is a kame according to this nomenclature; but it differs from the typical Scottish kames, as it is not fluvioglacial in origin. It is a glaciefluvial kame.

5. Other Varieties of Scottish Kames.

The most famous of the Scottish kames are those of Carstairs, which differ from the Polmont kame by their conspicuous false bedding and abundance of sand. Geologically the kames of Carstairs may be conveniently regarded as the typical representatives of kames. These kames form a range of hills which is usually composed of several ridges with the same general

[11] O. H. Hershey. "Eskers indicating stages of Glacial Recession in the Kansan Epoch in Northern Illinois." *Amer. Geol.*, vol. xix., 1897, p. 241.

[12] I. C. Russell. "Second Expedition to Mount St. Elias." *Thirteenth Annual Report U.S. Geol. Survey*, part ii., 1873, pp. 81-82.

[13] A summary of opinions on kames and eskers has been recently given in a paper "The Relations of Kames and Eskers." *Geogr. Journ.*, vol. , 1912, pp. .

[14] T. C. Chamberlin. "The Terminal Moraine of the Second Glacial Epoch." *Third Annual Report U.S. Geol. Survey*, p. 300.

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course; they are frequently confluent, and enclose basin-shaped depressions.

The kames are best defined in the neighbourhood of Carstairs from Ravenstruther to Carnwath, on a length of 5 miles. Their width here is often a quarter of a mile, and they rise in places 70 and 90 feet above the adjacent plains. They can be traced further east and west, and are continued as low, sandy mounds across the Clyde basin just above the upper fall of the Clyde.

The kames of Carstairs consist of sand and coarse gravel. The gravel is most prevalent and is coarsest on the northern side of the kames; it there consists of a torrential gravel, with layers of boulders, interstratified with beds of sand. This type of the material may be represented by the section beside the road north of Newhouse Farm, west of Carstairs; a gravel pit there discloses a layer crowded with boulders, below a bed of sand, and above a layer of sand containing scattered boulders. The sandy type of the kame is shown in the large railway pit near Carstairs Station, a little south-east from the manse. The kame there consists mainly of false bedded sand, with occasional boulders; and, as some of them retain their glacial striæ, they appear to have been deposited from floating ice.

The boulders and pebbles consist of rocks from the hills to the south. In the pit near Newhouse Farm there are boulders of Old Red Sandstone, of which the largest measured is 27 by 18 inches. There are also many quartzite pebbles from the Old Red Sandstone conglomerates, various Silurian and Ordovician greywackes from the Southern Uplands, pink Tinto felsites, Old Red Sandstone porphyrites, various basalts, and Carboniferous sandstones.

In the sandpit at Carstairs there are boulders of Carboniferous limestone and fragments of coal. Some of the boulders in the pit at Newhouse show the traces of glacial grooves, but I have not noticed there any well-preserved striæ. In spite of careful search on the last visit to that pit, no Highland schist pebbles were found.

The kames of Carstairs have been briefly described by Sir Archibald Geikie in the "Memoirs of the Geological Survey of Scotland" (Explanation of Sheet 23, pp. 43-44), and the explanation adopted there, and in Professor James Geikie's

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"Great Ice Age," third edition, 1894, p. 187, seems adequately to explain the facts. These kames have also been referred to as an example of an esker or "kaim" by A. C. Ramsay.[15]

The material in the Carstairs kames is clearly of a southern origin. The kames occur where the old glacier that descended from the Upper Clyde Valley spread out on to the level plains through which the Clyde flows from Carstairs to near Lanark. The glacier which brought the kame material probably spread out as a wide ice fan over this level land; and the kame was deposited on the margin of the glacier during one stage of its melting. No doubt part of the kame material was deposited by glacial rivers; the false bedding shows the action of strong shifting currents of water, and the sand beds near Carstairs may have been deposited in temporary glacial lakes between the glacier and the embankment formed by the kame. The kame was a fluvioglacial formation along the margin of the melting glacier.

The kame at Carstairs was formed by ice which came down the Clyde Valley between the Tinto Hills to the west and the Biggar Hills to the east. The height of the banks of the Clyde Valley in that district are shown by dotted and broken lines on Fig. 3, which has been kindly drawn by Mr. B. K. N. Wyllie. The glacier lay on the floor of the valley between, with the surface (G. G.) sloping downward to its end at Carstairs. The southern origin of the ice explains the striking contrast between the ground to the north and south of the kame line. The ground to the north is free from fluvioglacial material, while the country to the south is littered with irregular hummocks of sand and gravel.

Another well-marked kame runs across the hills near Chapelton and Strathaven, to the south of East Kilbride. This kame has been carefully examined by Mr. A. Stevens, and his description shows that it is similar in several respects to the kame at Polmont, though it is more sandy and stratified. It appears to have been formed on the margin of the glacier which flowed

[15] "The Eskers of Ireland and the Kaims of Scotland. These are common in the great valley of the Clyde, especially near Lanark and Carstairs, where they form vast elongated irregular mounds of gravel above the true glacial detritus." A. C. Ramsay. *The Physical Geology and Geography of Great Britain*, edit. iii., 1872, p. 174.

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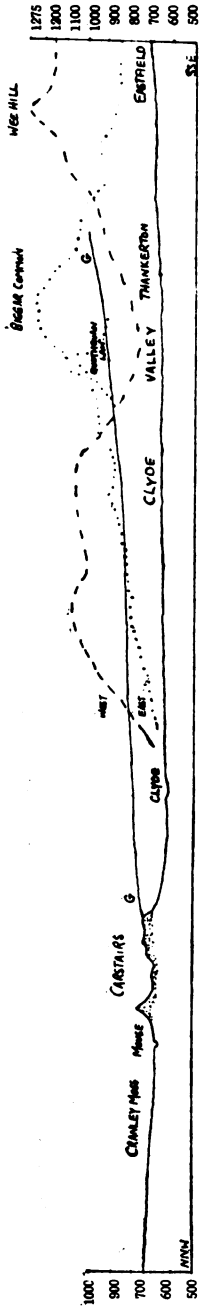

FIG. 3.

across the Glasgow basin from the north; and the kame was deposited when the ice edge had fallen to the level of about 800 feet.

The kames of a third variety may be called residual kames, as they are mounds formed by denudation of sheets of sand and gravel. They consist of fluvioglacial material, but their present forms are the results of post-glacial denudation. There are numerous examples of these mounds to the east of Glasgow. One series may be seen from the tramcar between Glasgow and Uddingston, about Mount Vernon (alt. about 100 feet above sea-level). The sand in the pits at Hamilton, well known from their pretty series of post-glacial faults, is of similar nature. It is probably the remnant of a sheet of sand and gravel deposited in a glacial lake formed by the Clyde when its outlet was still blocked by ice. The irregular kames near Gateside, between Kilsyth and Haggs, are also residual, and were probably formed in a glacier lake in the upper valley of the Kelvin. The relations of the fluvioglacial sheets of which these kames are the remnants have not yet been adequately determined.

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The Geological Survey Map, sheet 38, shows to the east of Balfron a long ridge which is marked as a kame, and in its ridge-like form it resembles an esker. But it has the characters of a moraine and not of a fluvioglacial deposit. This ridge crosses the high road about 1¾ miles north-east of Balfron Station, and it can be traced thence, gradually diminishing in size, for 3 miles to the north-north-west along the slope of the hills. It has been cut through by the Ballat Burn, from which it extends eastward on a curved line. The "green hill" east of Buchlyvie Station is probably a detached fragment of this moraine. The ridge north of Balfron road is studded with large angular boulders of Highland schist, and contains many well-rounded pebbles from the Old Red Sandstone conglomerates; but its structure is that of a typical moraine. It is a glacial and not a fluvioglacial formation. It seems to have been formed as the lateral moraine of the glacier, which came down from the mountains to the north of Ben Lomond. This glacier occupied the valley between the Ben Lomond and the Gualann ridge on the south-west, and the flattened, spurless, ice-worn face of the hills above Loch Chon, Loch Ard, and Aberfoyle on the north and north-east.

It may, no doubt, be sometimes difficult to draw a definite line between a kame and a gravelly moraine. A moraine which has been formed by the redeposition of beds of gravel will be unquestionably kame-like in composition; though in such a moraine a considerable number of the pebbles should be striated, though perhaps only faintly. A kame, on the contrary, should show definite signs of deposition by water. The similarity of kames and moraines has been noted in both British and American glacial literature, as in Professor J. Geikie's reference to kames as "gravelly moraines,"[16] and in the title of Professor Fairchild's paper, "The Kame Moraine of Rochester."[17] Jamieson described kames and eskers as morainic deposits, and gave a figure showing their formation as terminal moraines. There is, however, an important distinction between these fluvioglacial deposits and moraines, which are due to the accumulation of material where it falls from a melting glacier.

[16] James Geikie. "Structural and Field Geology," 1905, p. 312.

[17] H. L. Fairchild. "The Kame Moraine at Rochester, N.Y." *Amer. Geol.*, vol. xvi., 1895, p. 39.

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The positions of the kames referred to in this paper are shown on the sketch map, Fig. 4, which also states their approximate levels. The kames are best developed on the southern side of the Midland Valley, though those at Polmont and Chapelton were derived from ice which came from the north. The kames

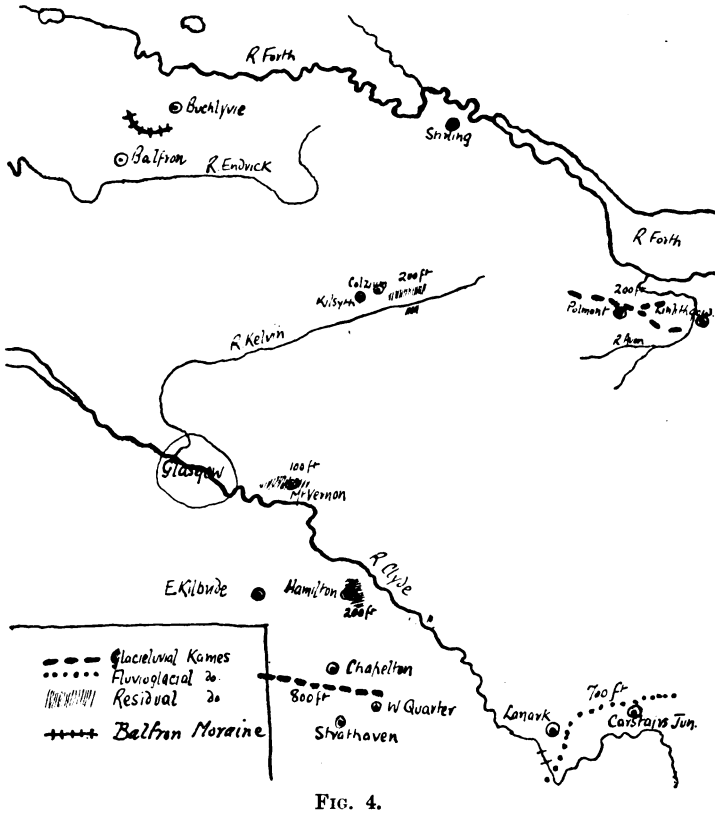

FIG. 4.

of Carstairs, on the other hand, were formed by ice, which entered the Midland Valley from the Southern Uplands.

6. THE UNITY OF THE GLACIAL FORMATIONS.

Another question suggested by the Polmont kame is whether it affords any evidence as to the existence of more than one glaciation in its neighbourhood. Was the kame formed by a

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younger ice sheet than the boulder clay? Were the kame and the drumlins to the north of it due to a later sheet of ice than the boulder clay to the south of it? The evidence, however, renders it most probable that the boulder clay on both sides of the kame was formed by the same sheet of ice, though the deposition of boulder clay continued longer on the northern than on the southern side of the kame. It seems impossible to explain the kame except as derived from the ice which laid down the drumlins to the north of it; and their material is identical in character with that of the boulder clay to the south of the kame.

The glacial deposits associated with the Polmont kame all appear to belong to one glaciation.

7. The Post-Glacial Denudation and its Duration.

As the Polmont kame retains its original form, it is interesting to consider whether the drumlins of boulder clay owe their form to original deposition or to subsequent denudation. The sheet of boulder clay was no doubt laid down with an irregular upper surface, and the present relief may retain some trace of the original undulations due to deposition; for the rain would collect in the depressions, which would be enlarged and connected by the streams. Hence the high ground at Laurence Park may represent an especially thick deposit of boulder clay, which has been denuded on its eastern and western slopes by the Avon River and the Gilston Burn respectively. The boulder clay hills have, however, certainly undergone extensive post-glacial denudation. The loamy nature of the soil shows that much of the boulder clay has been removed, for its sand represents the residue of a thick layer of boulder clay. The present topography can retain only imperfect traces of the original surface, though there may have been but little change along some parts of the course of the kame. The aspect of the drumlins on the western side of the Avon Valley, for example, suggests that they have been reduced to their present form and size by extensive denudation; and Dr. H. M. Cadell,[18] in his recent paper, maintains that the lower part of the Avon Valley was cut in post-glacial times.

[18] H. M. Cadell. "The Story of the Forth." *Scot. Geog. Mag.*, vol. xxviii., 1912, p. 250.

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As the kame and the drumlins to the north of it were laid down during the last stage of the retreat of the ice from this district, they give a good indication as to the amount of post-glacial denudation, and therefore of the period of time that has elapsed since the end of the glacial period in this part of Scotland. According to Baron de Geer, the ice has disappeared very recently from the plains of eastern Sweden. It may therefore be suggested that, if the Scandinavian and Scottish glaciations were synchronous, the glaciers may have withdrawn from the Midland Valley of Scotland only a very few thousand years ago. The evidence of the kame and drumlins near Polmont, however, indicates that this district has undergone considerable denudation since the retreat of the ice. No doubt erosion would have been especially rapid in some places at the close of the glaciation, owing to the floods set free from the melting ice; but as most of that drainage would have escaped to the North Sea down the estuary of the Forth, most of the flood water would not have acted on the Avon Valley. If the Polmont kame was continuous across that valley to Linlithgow, as was probably the case, then the valley has been greatly widened and deepened since the formation of the kame. Judging from some of the isolated hills in the Avon Valley, which rise above the 200-foot contour, the post-glacial denudation has eroded or re-excavated the valley by at least 60 or 70 feet in depth. The course of the Roman wall which passes over the drumlins to the north of the kame shows that there has been no appreciable change in the topography of the country or deepening of the valleys during the past eighteen hundred years. Great changes had, however, taken place between the formation of the kame and the building of the Roman wall. Hence it seems probable that the period since the glaciers disappeared from this part of Scotland must be reckoned by many thousands, and probably by many tens of thousands of years.

Figures.

1. Map of the Glacieluvial Kame of Polmont. From *Geog. Jour.*, vol. xl. p. 171.
2. Section N. and S. across kame and drumlins in 3 places.
3. The relations of the Carstairs Kames to the upper Clyde Valley glacier.
4. Sketch Map of the Kames.

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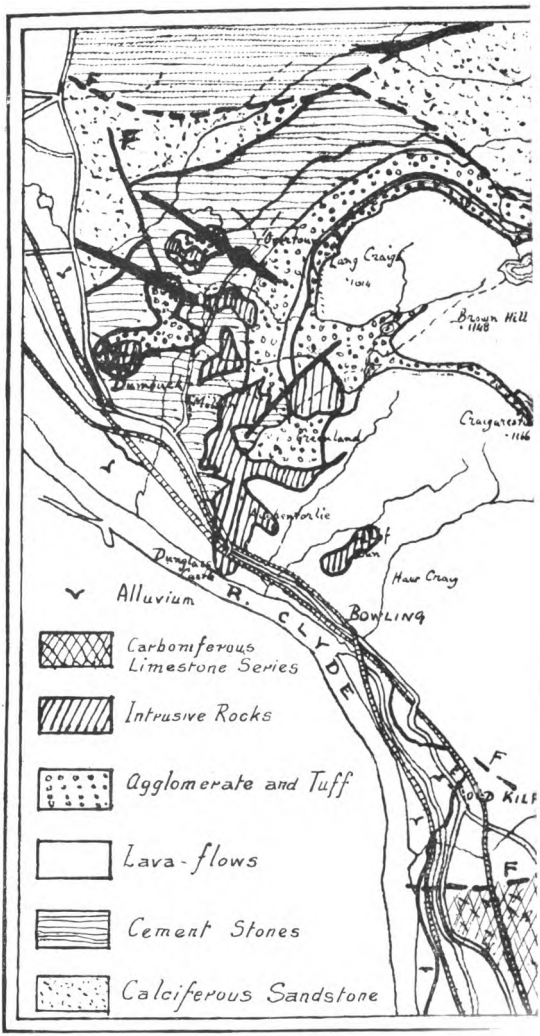

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No. IX.—The Petrology of the Kilpatrick Hills, Dumbartonshire; with Notes on the Scottish Carboniferous Basalts.

By G. W. Tyrrell, A.R.C.Sc., F.G.S., Assistant to the Professor of Geology, Glasgow University.

[Read 11th January, 1912.]

I. Introduction.

The Kilpatrick Hills form one of the elevated plateaux of volcanic rocks which diversify the great plain of the Midland Valley of Scotland. They are situated 9 miles north-west of Glasgow, partly in Dumbartonshire and partly in Stirlingshire. They are bounded on the west by the narrow valley of the Clyde at Bowling, and by the Leven valley. On the other side of the Clyde is a lower plateau of the same rocks, which, however, further to the west, culminates in the high ground of Misty Law. To the south the Kilpatrick Hills are bounded by low, undulating ground occupied by the Carboniferous Limestone Series, and belonging to the valleys of the Clyde and Kelvin. To the east and north-east the natural boundary is the broad depression of the Blane valley, although a narrow strip of lavas joins up the Kilpatrick Hills with the Strathblane Hills, on the other side of the depression. To the north the lava-plateau is bounded by a wide and open peaty moorland underlaid by porous sandstones. This bleak and desolate area is of somewhat lower elevation than the Kilpatrick Hills, and to the north-west slopes down to the low ground about the lower end of Loch Lomond. It is trenched by deep and narrow stream gorges, and it is dotted here and there with the green, conical hills marking the sites of ancient volcanic vents.

The Kilpatrick Hills thus consist of a rectangular block of volcanic rocks whose longer direction of extension is E.N.E. from Bowling (see Map, Fig. 1). In this direction, measuring from Bowling to Strathblane, the length of the plateau is about 8½ miles. The breadth, measured from Burn Crooks on the north to Douglas Muir on the south, is about 4 miles, and remains rather uniform. The area embraced is therefore roughly 34 square miles. The mean elevation of the plateau is

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about 1000 feet above sea level, the highest points being Duncomb and Fynloch Hill, each rising to 1313 feet.

From this upland region streams fall away on the north side to the Leven and the Blane Water, in the Loch Lomond drainage area; and on the south to the Clyde and Kelvin. As a rule the valleys are narrow and deep. At their heads the streams meander in small alluvial flats, which in some cases are due to lakes dammed up by glaciers in the Glacial Period. Many of these flats now form convenient sites of reservoirs for the growing communities on the borders of the plateau. Some of these reservoirs, however, feed the Forth and Clyde Canal. The history of the drainage system is rather complex, and a small contribution to its elucidation has been made in a former paper.[1]

The most prominent physiographic feature of the plateau is the terracing, due to the regular bedding of the lavas of which it is built. These terraces are extremely well defined over most of the area. Each corresponds to one flow, which has been worn back at the junction with the underlying flow where the soft, easily-weathered, brecciated, and vesicular upper and lower surfaces of the flows meet. There is evidence that some of the wearing-back may have been accomplished by a succession of landslides on the cliff margins of the terraces. The Whangie, at the N.W. corner of Auchineden Hill, is a famous example of these landslides, although it occurs in what is probably an intrusive rock. There are several smaller "whangies" in the same district.[2]

The regularity of the terracing is broken by the occasional intrusions, vents, and plugs, such as Duncomb and Fynloch, which penetrate the lavas.

II. Geological Relations.

The Kilpatrick Hills are built of a great succession of lava flows, and form part of Sir A. Geikie's aptly-named Clyde Plateau. This great area of regional volcanic activity originally stretched right across central Scotland from Stirling to the Mull

[1] Tyrrell and Martin, *Trans. Geol. Soc. Glasgow*, vol. xiii., pt. iii. (1909), p. 335.

[2] *Ibid.*, p. 329.

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of Kintyre, but is now broken into detached fragments, of which the Kilpatrick Hills is one, by denudation and faulting. The geological relations of the Clyde Plateau have been fully described by Sir A. Geikie, who has also given in the same place many details of the structure of the Kilpatrick Hills.[3]

The eruptions of the Clyde Plateau occurred mainly in Calciferous Sandstone times, and ceased before the deposition of the base of the Carboniferous Limestone Series. In the Kilpatrick Hills the lavas rest on the cement stone group which forms the upper part of the Calciferous Sandstone. These rocks occur around the northern and north-western margin of the plateau, and are well exposed in the Murroch and Auchenreoch Glens, near Dumbarton. The lavas are usually separated from the sedimentary rocks by a thick bed of tuff, and thin intercalations of tuff and cement stones occur at various horizons in the lavas.[4]

The southern boundary of the Kilpatrick plateau is generally faulted against the Carboniferous Limestone Series; but at Douglas Muir the lavas are conformably overlain by conglomerates and pebbly sandstones belonging to the lower part of the Carboniferous Limestone Series. Eastward the plateau may be regarded as bounded by the great Campsie fault, which extends along the Blane valley. A similar east to west fault probably occurs along the Clyde near Bowling, on the western edge of the plateau.

Structurally the Kilpatrick Hills may be described as a flat anticline pitching to the south-east at an angle of about 20°. The anticlinal structure is well seen in the profile of the hills from any good viewpoint (such as Scotstounhill) in the north-west of Glasgow.

III. The Classification of the Scottish Carboniferous Basalts.

(a) *Historical.*

Up to a late date the Calciferous Sandstone eruptives were generally described as consisting mainly of andesites (porphyrites), although the presence of basalts and even ultra-basic

[3] "Ancient Volcanoes of Great Britain," vol. i. (1897), pp. 368-370; *et seq.*

[4] *Ibid.*, fig. 120, p. 392.

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rocks, as well as trachytes and felsites, was remarked.[5] Recent chemical and microscopical research has shown that these "porphyrites" are all to be classed as basalts, and that no andesites in the proper sense of that term are present. The author has examined hundreds of thin sections of the Calciferous Sandstone and other Carboniferous lavas, but has not found a single typical andesite, similar to those, say, which are so abundant in the Old Red Sandstone volcanic piles of Scotland. The gap between trachyte and basalt is bridged, not by andesite as in a calcic series, but by mugearite, a rock with chemical affinities to the essexite family. This fact may be regarded as evidence for the mildly alkalic nature of the Calciferous Sandstone igneous rocks.

Some of the earliest descriptions of Scottish Carboniferous basalts are contained in a classic paper by Allport in 1874.[6] From the Kilpatrick Hills he described the Dunsapie basalt of the Hill of Dun, near Bowling. The first systematic classification was one by Sir A. Geikie in a paper on the "Carboniferous Volcanic Rocks of the Firth of Forth Basin."[7] He divided the volcanic rocks into (1) augite-felspar rocks, (2) olivine-augite serpentine rocks, (3) felspar-magnetite rocks, (4) felsite rocks. Of these, groups (2) and (4) are said to be scarce, the former including the picrites of Inchcolm and Blackburn, now known to be ultrabasic modifications of teschenites. The augite-felspar rocks are divided into (1) diabases, (2) dolerites, (3) basalts. The "diabases" are mostly the rocks of the great east-west dykes and their accompanying protrusions into the adjacent strata, and are now known as quartz-dolerite or granophyric diabase. The dolerites are characterized by ophitic structure and include various intrusive rocks, principally of the teschenite group. The basalts include the more basic types of the Carboniferous lavas. The Craiglockhart basalt is described as "anamesite," and a Hillhouse basalt from Kirkton, Bathgate, is also treated in some detail. The third main group—"felspar-magnetite rocks"—include the porphyrites, probably Markle

[5] Sir A. Geikie, Pres. Address, *Q.J.G.S.*, vol. xlviii (1892), p. 111 "Ancient Volcanoes of Great Britain," vol. i. (1897), p. 379.

[6] *Q.J.G.S.*, vol. xxx. (1874), pp. 529-567.

[7] *T.R.S.E.*, vol. xxix. (1879), pp. 486-516.

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basalts and mugearites, and also the orthophyres (trachytes) of the Garleton Hills.

In the "British Petrography," Dr. Teall described the Lion's Haunch type, the Dunsapie basalt of the Hill of Dun, and the glassy Jedburgh of Dunglass Hill, near Strathblane.[8]

The detailed subdivision of the Scottish Carboniferous basalts was continued by Dr. Hatch in 1892, at the request of Sir A. Geikie.[9] The main divisions recognised by Hatch were—

(*a*) Basalts with olivine.
(*b*) Basalts without olivine.

The basalts with olivine were sub-divided into five groups characterized by certain mineralogical and structural characters. A particular locality was named in each case as a reference or type locality (although the word "type" was not here used). The five places thus mentioned were Hillhouse (Bathgate Hills), Dalmeny, Gallaston, Lion's Haunch (Arthur's Seat), and Craiglockhart. The basalts without olivine were not subdivided.

Following in the same paper, the intrusive rocks of the Carboniferous were described, and such terms as limburgite, picrite, olivine dolerite and diabase, olivine-free dolerite, &c., were used for rocks now known as monchiquite, nepheline and analcite-basalt, picrite and teschenite, and quartz-dolerite.

In the same year Dr. Hatch described the igneous rocks of the Garleton Hills, East Lothian.[10] Various basaltic types were established in this paper. The Markle type was defined by the highly felspathic and porphyritic rock of Markle Quarry; the limburgite of Whitelaw Hill was described, and the possibility of it containing nepheline, since demonstrated, was indicated. A "Kippie Law" type was also established for a rock with porphyritic felspar and olivine; but Mr. Bailey has shown that this rock is really a Dunsapie basalt, the slide upon which Dr. Hatch based the type accidentally containing no porphyritic augite.[11]

In 1897 Professor W. W. Watts, at the request of Sir A.

[8] *Brit. Petrog.* (1888), pp. 188; 193.

[9] *Q.J.G.S.*, vol. xlviii. (1892), p. 129.

[10] *T.R.S.E.*, vol. xxxvii. (1892), pp. 115-126.

[11] *Mem. Geol. Sur.* "Geology of East Lothian" (1910), p. 119.

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Geikie, revised and supplemented the classification of Dr. Hatch.[12] His main divisions were—

1. Olivine-bearing Series.
2. Non-olivine-bearing Series.

Each was subdivided into ophitic and non-ophitic groups, the former being termed dolerites and the latter basalts. Further subdivision was effected by mineralogical difference, the various types being associated with and indicated by particular localities in the majority of cases, but inconsistently by petrographical or structural terms in the remainder. This classification concerned only dolerites and basalts belonging to the Calciferous Sandstone, and to the Carboniferous Limetone puy eruptions. Amongst Calciferous Sandstone eruptives Sir A. Geikie distinguishes, besides dolerites and basalts, augite-olivine rocks (picrite and limburgite), andesites (porphyrites), and "trachytes." The latter rocks were sometimes undoubtedly mugearites, as can be seen from the very exact megascopic description;[13] but the orthophyres and trachytes of the Garleton Hills were also included. The andesites (porphyrites) are said to be the most abundant lavas of the plateaux.

In 1904 Dr. J. D. Falconer described the basalts of the Bathgate and Linlithgow Hills, and divided them into five groups, all except one being rocks with porphyritic olivine and augite. These are mostly Dalmeny and Hillhouse basalts.[14]

The question of the classification of the Carboniferous basalts was taken up again by the officers of the Geological Survey of Scotland during their revision of the coalfields of the Midland Valley. Scattered notes are to be found in various "Annual Summaries of Progress," but the full statement of their views is contained in three recent memoirs, the petrology of which has been done by Dr. J. S. Flett and Mr. E. B. Bailey.[15]

[12] "Ancient Volcanoes of Great Britain," vol. i. (1897), p. 418.

[13] ". . . Trachytes, grey to pink in colour, but apt to weather yellow, exceedingly compact, sparingly porphyritic, and with a peculiar platy structure and waxy lustre." "Ancient Volcanoes of Great Britain," vol. i. (1897), p. 380.

[14] *T.R.S.E.*, vol. xlv. (1906), pt. i., pp. 133-6.

[15] *Mem. Geol. Survey.* "The Geology of East Lothian" (1910), pp. 118-127. "The Geology of Edinburgh," (1910), pp. 316-323. "The Geology of the Glasgow District" (1911), pp. 135-145.

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Whilst many of the type-names instituted by Dr. Hatch and Professor Watts have been retained, their main and subsidiary grouping has been abandoned, at least by Mr. Bailey, and replaced by a classification into macroporphyritic and micro- or non-porphyritic types with further subdivision on the basis of phenocrysts. Besides being very simple, this classification has the further advantage of being largely applicable to the rocks in hand specimens without the labour of having to make thin sections. In the "Edinburgh Memoir," Dr. Flett still retains a third division characterized by ophitic texture, in addition to groups characterized by "conspicuous phenocrysts" and "small and inconspicuous phenocrysts" respectively. In this he includes the Jedburgh, Kilsyth, and Gallaston types. The main distinction of the earlier classifications between olivine and non-olivine-bearing types has not much real significance; neither has the subsidiary distinction between ophitic and non-ophitic. As is shown later (p. 235), both textures may occur in a single intrusion. The later classification of the Scottish Carboniferous basalts is based on real mineralogical difference, either qualitative or quantitative, and this finds expression in real, though comparatively small, chemical differences. They form a continuous series within a small range of variation and are easily grouped around a few arbitrarily-defined types, which are connected by numerous intermediate varieties. The history of their classification is carried further in the following section.

(b) *Detailed Classification.*

As the Kilpatrick Hills consist entirely of basalts (including mugearites), this survey will be concerned only with the classification of basaltic types, and will not deal with the special varieties of trachydolerite, trachyandesite, trachyte, phonolite, and felsite which have been described as occurring with the plateau eruptions in other localities.

1. *Microporphyritic Basalts.*

The *mugearites* were first described by Harker from various localities in Skye.[16] They are basalt-like rocks, the felspar

[16] "Tertiary Igneous Rocks of Skye" (1904), pp. 256-69.

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of which is mostly oligoclase. They are poor in bisilicate minerals, but usually contain a fair amount of olivine and iron ores, especially the latter. A certain amount of orthoclase mingles with the plagioclase felspar. In Skye the mugearites form composite sills of Tertiary age along with a highly porphyritic type of olivine-dolerite. This association is interesting, in view of their occurrence in the Carboniferous rocks associated especially with porphyritic lavas of the Markle type. The Carboniferous mugearites were first recognised by Mr. Barrow[17] in East Lothian; and subsequently they were found to have a wide distribution in the Clyde plateau.[18]

Essentially the mugearites are oligoclase basalts, and are chemically allied to the essexite family. They pass to Jedburgh basalt along one line of transition with increasing abundance of a basic plagioclase felspar. Some types are porphyritic with labradorite felspar, and, with increasing abundance of the porphyritic element, pass into the Markle type. The mugearites have a very characteristic field aspect (p. 224).

The *Jedburgh* type was founded by Professor W. W. Watts for rocks with a sub-ophitic groundmass of felspar and augite, and carrying inconspicuous phenocrysts of felspar and olivine, of which the latter is most abundant.[19] The group has been extended by Mr. E. B. Bailey to include "basalts and fine-grained dolerites which carry microphenocrysts of felspar and olivine in a nearly holocrystalline groundmass of felspar and augite."[20] Whilst the texture is characteristically ophitic, there are included rocks of similar mineralogical composition in which the groundmass is microlitic, cryptocrystalline, or even glassy (Dunglass, Strathblane). The proportion of felspar and olivine phenocrysts, whilst approximately equal in typical rocks, may vary considerably. A considerable number of rocks in the Kilpatrick Hills carry abundant olivine relatively to the felspar, and are thus intermediate between the Jedburgh and Dalmeny types. With ophitic

[17] *Summ. Prog. Geol. Sur. for 1903* (1904), p. 99.

[18] *Mem. Geol. Sur.*, "Geology of the Glasgow District" (1911), pp. 140-2.

[19] "Ancient Volcanoes of Great Britain," vol. i. (1897), p. 418.

[20] *Mem. Geol. Sur.*, "Geology of the Glasgow District" (1911), p. 138.

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texture these rocks form the *Gallaston* type of Hatch. Mr. Bailey remarks that the restriction of augite to the groundmass is one of the main features of the Jedburgh type. In the Kilpatrick Hills, however, there are rocks in which microphenocrysts of augite appear as well as felspar and olivine. In fact, they might be regarded as a microporphyritic equivalent of a Dunsapie basalt, were they not much more felspathic than that type. There seems to be no reason for erecting a new type to accommodate these rocks; the definition of Jedburgh basalt might well be extended in order to cover them. The Jedburgh type would then be defined as basalts containing microphenocrysts of felspar, olivine, and occasionally augite in a groundmass which is dominantly felspathic. The latter is probably the most essential feature, and links the Jedburghs to the highly felspathic mugearites and Markle basalts, with which they are closely associated in the field.

The Jedburgh basalts may pass into Markles in two ways; either by the appearance of sporadic macrophenocrysts of felspar, or by a gradual increase in the size of the microporphyritic felspars. Transitions along both lines are common in the Kilpatrick Hills. Also, as Mr. Bailey has pointed out, the Jedburgh basalts pass into mugearites by an increasing alkalinity of the felspars, giving rise to *basaltic mugearites*.

The Jedburgh, Markle, and mugearite basalts are inseparably connected both petrographically and in the field. It is well to emphasize the fact that all the "types" enumerated here are merely arbitrary centre-points around which rocks belonging to a continuous series may be conveniently grouped. The "types" merge insensibly into one another, and the Kilpatrick Hills, as well as probably others of the plateaux, are composed mainly of intermediate varieties.

The *Dalmeny* type was instituted by Hatch for basalts with numerous small olivines and grains of augite in a mesh of slender plagioclase laths, with microlitic augite and magnetite.[21] This definition is adopted with little modification by Watts, Flett, and Bailey. Stress is laid on the abundance of microphenocrystic olivine. The appearance of microporphyritic felspar and augite links these rocks with the

[21] *Q.J.G.S.*, vol. xlviii. (1892), p. 130.

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Jedburghs, of which both ophitic and non-ophitic types tend to pass to the Dalmeny by an increase in olivine relative to felspar. The Dalmeny basalts are one degree more basic than the Jedburghs. True Dalmeny basalts are not common in the Kilpatrick Hills. They have been met with about the middle of the succession in the central and western traverses.

Hillhouse Type.—The basalt of Hillhouse Quarry, Bathgate Hills, was first mentioned by Dr. Hatch and described under the heading of "basalts with olivine." It is described as "containing large porphyritic olivines . . . , granular augite, scattered grains of magnetite, and only a small amount of felspar, thus approaching picrite."[22] This definition is substantially repeated by Professor Watts, who describes the rock as "picrite" type, and says that porphyritic olivine is much more common than augite.[23] The type is described by Dr. Flett, who first used the term "Hillhouse type," under his Group II.—Basalts and dolerites—"Rocks with small and inconspicuous phenocrysts in a finely cryptocrystalline or partly glassy groundmass, not ophitic."[24] The type may be defined as containing numerous microphenocrysts of olivine and less abundant augite with a groundmass of augite, magnetite, and felspar, in which the first-named largely predominates. Mr. Bailey states that analcite or glass accompanies the basic felspar in the groundmass.[25] Only one or two basalts near the Hillhouse type have been found in the Kilpatrick Hills, and these rocks might be regarded as microporphyritic Craiglockhart basalts (p. 231).

Monchiquite, Nepheline and Analcite Basalt, and Limburgite.—Dr. Hatch first described rocks of this type as "limburgite," and suggested the possible presence of nepheline.[26] The later development of the nomenclature is due to Bailey.[27] These various rocks all agree in the absence of felspar and in the abundance of microphenocrysts of olivine and augite. The groundmass always contains very numerous

[22] *Q.J.G.S.*, vol. xlviii. (1892), p. 129.
[23] "Ancient Volcanoes of Great Britain," vol. i. (1897), p. 418.
[24] *Geol. Sur. Mem.*, "Geology of Edinburgh" (1910), p. 316.
[25] *Ibid.*, "Geology of the Glasgow District" (1911), p. 138.
[26] *T.R.S.E.*, vol. xxxvii. (1892), p. 117.
[27] *Mem. Geol. Sur.*, "Geology of East Lothian" (1910), pp. 105-113.

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microlites of augite embedded in an isotropic matrix in the case of the monchiquites and analcite basalts. In the nepheline basalts identifiable nepheline occurs along with analcite; and in the limburgites the isotropic base is a glass. The distinction between monchiquite and analcite basalt is vague; the monchiquites, however, should have an overwhelming proportion of femic constituents and a scanty though pervading base of analcite; whilst the latter mineral should be in considerably greater proportion in the analcite basalt. Mr. Bailey has separated the *Kidlaw type* as a special variety of analcite basalt characterized by relatively abundant orthoclase and biotite as compared with the other rocks of the group, and by the fact that its analcite occurs in large, distinct, poecilitic crystals. Rocks belonging to this group have not been met with in the Kilpatrick Hills.

2. *Macroporphyritic Basalts.*

The *Markle* type was instituted by Dr. Hatch for the "labradorite basalt" of Markle Quarry, in East Lothian.[28] This rock contains large and numerous phenocrysts of labradorite with small grains of olivine, in a groundmass of felspar, augite, and magnetite, the first-named being dominant. The rocks designated "porphyrite" by the older authors belonged principally to this type, which has a very wide distribution in the plateau lavas, and naturally attracted much attention.

In Watts' classification this rock is probably represented by the Kilsyth type, although this term was restricted to rocks with a sub-ophitic groundmass. The Markle basalts of East Lothian have been thoroughly investigated by Mr. Bailey.[29] He notes that the felspar phenocrysts may constitute half the rock, and that a considerable amount of alkali felspar (oligoclase and orthoclase) may be present. The Markle basalts are closely allied to the Jedburghs, and might be regarded as macroporphyritic varieties of that type. Intermediate varieties are very common in the Kilpatrick Hills, as well as the Markle and Jedburgh types proper. Mr. Bailey includes these intermediate varieties under the Markle type, and says

[28] Hatch, loc. cit., p. 119.

[29] *Mem. Geol. Sur.*, "Geology of East Lothian" (1910), p. 120.

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they "are in fact typical Jedburgh basalts with the addition of large labradorite phenocrysts."[30] This, however, rather impairs the utility of the classification for field purposes. The labradorite phenocrysts may be few and far apart, and large hand-specimens may be obtained without a single large phenocryst. These rocks are clearly more conveniently classed with the Jedburgh basalts. It is impossible to separate the two types, which pass gradually into one another along two lines of transition. In the Kilpatrick Hills true Markle basalts are abundant everywhere.

Dunsapie Type.—This term, first employed by Bailey,[31] is used for rocks with macrophenocrysts of felspar, augite, and olivine in a groundmass of felspar, augite, and magnetite. The type-rock is from Arthur's Seat. The term Dunsapie has been substituted for Lion's Haunch, which was formerly a frequent designation for rocks of this type, because the rock from the latter locality has a glassy groundmass, unusual in this group.[32] It also replaces Hatch's term "Kippie Law," since the slide upon which the description of this type was based accidentally did not represent the rock from which it was taken. Although a Dunsapie type it was consequently described as devoid of augite phenocrysts (p. 223). Dr. Flett retains the term Lion's Haunch for the Dunsapie rocks as defined above, and says the groundmass may be either granular and holocrystalline, or may contain a small amount of glass. The Dunsapie type is described as similar to this, but with a coarser groundmass, which usually contains some analcite and biotite.[33] It is better perhaps to use the term Dunsapie as a broad designation for all the basalts characterised by porphyritic olivine, augite, and felspar, retaining Lion's Haunch as a varietal term for those containing, in addition, some glass in the groundmass.

Teall described Lion's Haunch and Dunsapie basalts in the "British Petrography."[34] In the Kilpatrick Hills Dunsapie

[30] *Ibid.*, "Geology of the Glasgow District" (1911) p. 137.

[31] *Ibid.*, "Geology of East Lothian," p. 119.

[32] I am indebted for this information to Mr. Bailey, to whom I wrote, as in the East Lothian Memoir no reason was assigned for the adoption of the term "Dunsapie" in place of "Lion's Haunch."

[33] *Mem. Geol. Sur.*, "Geology of Edinburgh" (1910), pp. 316-317.

[34] (1888), pp. 188; 193.

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basalts are abundant towards the middle of the succession, especially in the eastern area.

Craiglockhart Type.—The Craiglockhart rock was first described by Sir A. Geikie as an "anamesite."[35] Dr. Hatch defined the type as a basalt containing porphyritic olivine and augite in a partially glassy base.[36] Professor Watts repeats this definition, with the difference that the groundmass is said to be made up of felspar laths embedded in augite granules—more rarely idiomorphic augite embedded in felspar substance.[37] The term is now used for basalts with conspicuous macrophenocrysts of olivine and augite.[38] The groundmass of the type-rock of Craiglockhart is holocrystalline and consists of granular augite, plagioclase, magnetite, and ilmenite.[39] Mr. Bailey notes that these basalts closely resemble the porphyritic essexite of Lennoxtown. They might also be regarded as the macroporphyritic analogues of the Hillhouse basalts, to which they closely approximate in chemical composition.

In the Kilpatrick Hills good Craiglockhart basalts are obtained near the Black Loch, about the middle of the succession, and also, sparingly, from one or two other localities.

The three types of macroporphyritic basalt pass into each other by insensible gradations and form a regular series showing straight-line variation.[40] On the basis of classification by phenocrysts of olivine, augite, and plagioclase, there are seven possible types—

I.	Plagioclase, olivine, and augite,	Dunsapie type.
II.	Plagioclase and olivine,	Markle (in part).
III.	Plagioclase and augite,	———
IV.	Olivine and augite,	Craiglockhart.
V.	Plagioclase only,	Markle (in part).
VI.	Olivine only,	Represented by a few basalts (Cathkin Braes).
VII.	Augite only.	———

Up to the present it has only been found necessary to use three

[35] *T.R.S.E.*, vol. xxix. (1880), p. 500, pl. xi., figs. 3, 4.
[36] *Q.J.G.S.*, vol. xlviii. (1892), p. 130.
[37] "Ancient Volcanoes of Great Britain," vol. i. (1897), p. 418.
[38] *Mem. Geol. Sur.*, "The Geology of East Lothian" (1910), p. 118.
[39] "Geology of Edinburgh" (1910), p. 318.
[40] See diagram, "Geology of East Lothian" (1910), p. 122.

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of these types, or four, since the Markle basalts probably include rocks belonging to both II. and V. This points to the necessity of restricting the term Markle to type II. or V.

The microporphyritic basalts also form a good variation diagram (opposite p. 252). These facts seem to show that the classification adopted for practical reasons has its basis in true petrogenetic relations.

A synopsis of the classification of the Scottish Carboniferous basalts is given in the table (pp. 233-4).

Petrography of the Kilpatrick Hills.

Jedburgh Basalts.—These are dominantly felspathic basalts, not macroporphyritic, consisting of a groundmass of plagioclase, augite, and magnetite, in which the felspar is dominant, usually with numerous microphenocrysts of labradorite and less of olivine. They are divisible into several sub-groups. In some varieties numerous microphenocrysts of augite occur, as well as felspar and olivine. The microphenocrysts may increase in size until the rock merges into a Markle basalt. On the other hand the olivine may so increase relatively to the felspars that the rock passes into a Dalmeny type; or the felspars may become more alkaline, thus affording gradations to the mugearites. The groundmass may be ophitic or microlitic, cryptocrystalline or glassy. Dominantly felspathic basalts entirely devoid of phenocrysts of any size may be included in the Jedburgh group.

The Jedburgh basalts as originally defined were ophitic; but a great number of the type having a microlitic or intersertal texture are conveniently included here. The ophitic variety is well represented by the intrusive rock of the Little Caldon vent on Stockiemuir. This rock has been described and analysed by the Geological Survey.[41] It is built of a plexus of labradorite and augite in ophitic relations, intermixed with scattered euhedral magnetite and serpentinous material, and studded with numerous microphenocrysts of labradorite and fresh olivine. The felspars are mostly of the composition Ab_1 An_1 and are occasionally highly zonal. There seems to

[41] *Mem. Geol. Sur.*, "Geology of the Glasgow District" (1911), pp. 138; 142.

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SYNOPSIS OF THE CARBONIFEROUS BASALTS.

TYPE.	DISTINGUISHING CHARACTERS.	REMARKS.
A. MICROPORPHYRITIC BASALTS.	Phenocrysts visible in thin section only.	Form a continuous series.
1. *Mugearite*, - - -	Felspar mostly oligoclase; some orthoclase; olivine and augite usually present, and magnetite and apatite abundant.	"Oligoclase basalt."
2. *Jedburgh type*, - -	Microphenocrysts, olivine and plagioclase; *g.m.* felspathic, with some augite and magnetite.	Texture usually ophitic or micro-ophitic; but often microlitic.
2*a*. *Gallaston type*, -	Abundant olivine, occasionally macroporphyritic, otherwise similar to Jedburghs.	This originally defined as with ophitic texture. The rock comes most naturally between the Jedburgh and the Dalmeny types.
3. *Dalmeny type*, - -	Numerous microphenocrysts of olivine; plagioclase and augite rare or absent; *g.m.* slender plagioclase laths with abundant microlitic augite and magnetite.	Occasionally olivine phenocrysts macroporphyritic (Cathkin Hills). These should strictly come under the macroporphyritic basalts.
4. *Hillhouse type*, - -	Microphenocrysts of olivine and augite, the former predominating; *g.m.* mostly augite with a little basic plagioclase and analcite or glass.	This is the "picrite" type of Hatch.

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SYNOPSIS OF THE CARBONIFEROUS BASALTS.—*continued.*

TYPE.	DISTINGUISHING CHARACTERS.	REMARKS.
5. *Ultrabasic Analcite and nepheline-bearing basalts,* - - -	Numerous microphenocrysts of olivine and augite in felspar-free groundmass.	These occur chiefly as intrusive rocks, but are more conveniently classified with the basalts than with the intrusive teschenites, essexites, &c.
a. Monchiquite lava, -	*G.m.*—augite and magnetite with interstitial analcite or glass.	
b. Analcite basalt, -	*G.m.*—augite and magnetite, with conspicuous analcite.	Limburgite of Hatch, from Chester's Quarry, East Lothian. These rocks numerous in Late Carboniferous Lavas of Mauchline district.
c. Nepheline basalt, -	,, ,, ,, with nepheline, generally also with analcite.	
d. Kidlaw basalt, -	*G.m.*—with some felspar, notably orthoclase; biotite and analcite conspicuous; the latter in large poecilitic crystals.	A special variety of the analcite-basalts.
B. MACROPORPHYRITIC BASALTS, - - -	Conspicuous and identifiable phenocrysts in hand specimens.	Form a continuous series.
1. *Markle type,* - -	*Phenocrysts*—labradorite abundant; olivine less abundant. *G.m.*—felspar, augite and magnetite, the former dominant.	Transitions to mugearite, Jedburgh and Dunsapie types.
1*a. Kilsyth type,* - -	Similar to Markle, but *g.m.*, ophitic.	"Porphyrites" of older descriptions.
2. *Dunsapie type.* - -	*Phenocrysts*—labradorite-bytownite, augite, olivine. *G.m.*—felspar, augite and magnetite, occasionally a little analcite and biotite.	The Lion's Haunch type of many authors.
2*a. Lion's Haunch type,*	Similar to the Dunsapie, but with glass in the groundmass.	
3. *Craiglockhart type,* -	*Phenocrysts*—olivine, augite. *G.m.*—augite, felspar, magnetite.	

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be no discontinuity in size and generation between the small ophitic felspars and the microphenocrysts. They are connected by all gradations in size, and the larger crystals are also occasionally in ophitic relations with augite. The olivine is idiomorphic and comparatively fresh, having the ophitic augite moulded on it. The augite is in irregular plates much cut up by the enclosed felspars, and has a very distinct pleochroism, the extreme tints being pale sepia and purplish brown.

Similar rocks are obtainable from the vents around the northern and western margin of Auchineden Hill. The plug in the small vent north of the Whangie is an ophitic type in which the magnetite has a rod-like microlitic habit, and is enclosed in peculiar arborescent forms in the felspars. The Cathythirsty plug, bordering the Drymen Road, has remarkably deep-coloured augite with a correspondingly intense pleochroism. It is, moreover, a coarse doleritic type. An exactly similar rock occurs as a dyke cutting the tuffs at the base of the Lang Craigs, ½ mile N.E. of Overtoun. The intrusion at Burn Crooks is remarkable in that it is ophitic near the surface, but microlitic with a marked "bead-texture" at a depth of 144 feet, as obtained from a boring.[42] Both ophitic and microlitic varieties, the latter probably a contact-facies, are obtained from the intrusion of the Little Caldon vent on Stockiemuir.

Several of the lowermost lavas of Auchineden Hill and the district N. of the Kilmannan Reservoir are of the ophitic variety. The basal flow of Auchineden Hill carries a few large sporadic phenocrysts of felspar. In some of the lavas, notably those of Craigherstan, near the Kilmannan Loch, the augite is not uniformly distributed, but forms large, elongated, isolated patches riddled with laths of felspar.

The typical ophitic Jedburgh basalts occur mainly at the north-eastern extremity of the Kilpatrick Hills, either as intrusions in the vents or as the lowermost lava flows. A few, however, occur at other localities, as, for example, near the southern boundary-fault at Auchnacraig, near Faifley.

The *microlitic* varieties of the Jedburgh basalts are nearly as numerous as the ophitic. The best example is from a bore in the Burn Crooks or Knockvadie sill on the dam-site

[42] Tyrrell, *Trans. Geol. Soc. Glasgow*, vol. xiii., pt. iii. (1909), pp. 338-9.

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of the Clydebank Waterworks, about 1 mile N.W. of Auchineden Hill. As before stated, this rock has the ordinary ophitic texture near the surface, but specimens from a depth of 144 feet are beautifully microlitic. The rock is highly felspathic and the felspar laths have a distinct fluidal orientation. The augite occurs as pale, subhedral grains arranged in single rows wedged in between adjacent laths of felspar, and interspersed with less numerous, but larger, euhedral crystals of magnetite. This gives an appearance similar to that of more or less parallel rows of beads.[43] This bead-like texture appears to be highly characteristic of groundmasses in which the augite is very subordinate in quantity. Embedded in this groundmass are numerous microphenocrysts of serpentinized olivine, and an occasional large felspar, although there is no definite microporphyritic generation of felspar. Whilst generally restricted to the rows wedged in between the felspars, the augite may form little knots along with magnetite to the almost complete exclusion of felspar.

Similar rocks, but finer grained and richer in magnetite, occur in the second, fourth, and sixth flows of Auchineden Hill; the main escarpment on the west side of Craigarestie; and the eleventh flow above Old Kilpatrick. In the latter, as well as in the topmost flow of Craigarestie, the felspar occurs in a definite, abundant, microporphyritic generation. A coarse doleritic variety, in which the beaded texture is lost, forms the ninth flow of the Lang Craigs and the great escarpment of the Haw Craig above Bowling. Some of the microlitic varieties carry rather numerous microphenocrysts of augite, notably the fourth, tenth, and twelfth flows above Old Kilpatrick, and the fourth flow west of the Black Loch. In all other respects these rocks are Jedburgh basalts, and cannot be included in any of the other microporphyritic types.

Several of the Jedburgh basalts of the Kilpatrick Hills show an approach to the Dalmeny type by a considerable increase in the abundance of olivine microphenocrysts relatively to felspar. The groundmass, however, remains felspathic, and is not as basic as that of the typical Dalmeny basalts. The gradation takes place through both ophitic and microlitic

[43] Tyrrell, loc. cit., pl. xxi., fig. 2.

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varieties. Examples of the latter are afforded by the intrusions in the Dumbuck and Dumbarton Castle vents. In these rocks very numerous euhedral microphenocrysts of fresh or partially serpentinized olivine are set in a groundmass of dominant highly-zonal felspars and subordinate euhedral grains of augite and magnetite. The felspar laths are ill-defined, and only occasionally reach microporphyritic dimensions, but there is no definite early generation. These rocks closely resemble that of Edinburgh Castle, but their groundmass is much more felspathic.

Some remarkable micro-ophitic varieties, intermediate between the Jedburgh and Dalmeny types, occur in the flows above Old Kilpatrick. These rocks consist of a crowded mass of slender felspars with perfect fluxional arrangement embedded in deeply-tinted purple augite, which is cut up into thin shreds, strips, and triangular fragments by the felspar. The plates of augite themselves are numerous and elongated in the direction of flow. The felt of augite and felspar is interrupted by numerous microphenocrysts of serpentinized olivine and magnetite. This variety is distinguished by the combination of trachytic and micro-ophitic textures.

Whilst passing to Dalmeny types on the one side, on the other the Jedburgh basalts show transitions to the mugearites by increasing abundance of alkali-felspar and magnetite, with decrease of augite and olivine. In the field the mugearitic rocks are characterized by a pale weathering and a platy fissility.[44] The pale weathering, however, is also to be found on typical Jedburgh basalts, as is well seen at Burn Crooks and in Auchineden Hill.[45] Most of the "basaltic mugearites" are highly felspathic, more so than the Jedburgh basalts proper, and the felspar is largely a straight extinguishing variety—oligoclase. There is always, however, a considerable quantity of more basic felspar ranging in composition from Ab_1 An_1 to Ab_3 An_2. Granules of augite occur interstitially along with abundant magnetite. Olivine is variable in quantity, ranging from abundance in some of the rocks to absence in others. The texture is always more or less trachytic,

[44] *Mem. Geol. Sur.*, "Geology of the Glasgow District" (1911), p. 141.
[45] Tyrrell, loc. cit., pp. 323; 338.

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the fluxion-structure sometimes being very perfect. Some of these basaltic mugearites show an approach to the Markle type by the entrance of macrophenocrysts of labradorite felspar. In one of these porphyritic types from the road to Craigallian, 2½ miles N.N.W. of Milngavie, there is a good deal of residual untwinned felspar, occupying spaces comparatively free from ferro-magnesian minerals. This is probably orthoclase. In this rock the porphyritic felspars are aligned in the direction of flow, and there are also a few microphenocrysts of a pale-coloured augite. The basaltic mugearites are found associated with the Jedburgh basalts and Markle basalts, especially towards the base of the succession. There are several flows in Auchineden Hill, in the district N. of Milngavie, and in one or two of the higher flows of the central traverse on Cochno Hill.

A large group of basalts connect the Jedburgh with the Markle type. The transition may occur in two ways—by an increase in size of the microporphyritic felspars, or by the entrance of sporadic macrophenocrysts of felspar into a typical Jedburgh groundmass. These rocks all agree in possessing numerous microphenocrysts of serpentinized olivine, and the microlitic type of groundmass. They occur in all parts of the Kilpatrick Hills where Markle and Jedburgh types are frequent.

The chemical composition and standard mineral composition of a typical ophitic Jedburgh basalt is given in Table III., column iii., and of a basaltic mugearite, in Table III., column iv.

Mugearite.—The basaltic mugearites above described form a large intermediate series connecting the Jedburgh basalts with the mugearites proper. The latter rocks are devoid of basic felspar (labradorite). The plagioclase content is entirely oligoclase, with some orthoclase (p. 251, Table IV., col. v.). They do not appear to be quite so abundant in the Kilpatrick Hills as the basaltic mugearites.

Mugearites occur most abundantly in an area in the south-eastern part of the Kilpatrick Hills, near Milngavie, and are well exposed in the Cauldstream Burn. They also occur in parts of the central traverse (p. 254). In the field they form light-weathering, fissile, and easily decomposable rocks, recognizable without much difficulty. Under the microscope their texture and composition are often much obscured by decomposition, but by careful examination of the thin edges of sections

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the nature of the felspar which forms the great mass of the rock can be made out. On diaphragming the light below the section certain rectangular or lathy felspars are shown up in relief on an apparently continuous base of less highly refracting and more decomposed felspar. The former has a refractive index about equal to, or slightly greater than, that of Canada balsam, shows good albite-twinning, with extinction ranging up to 5°, and is clearly oligoclase. The other felspar is harder to make out. It frequently shows undulose extinction, but is untwinned, and has a refractive index less than that of balsam. Its characters correspond to those of orthoclase, and this diagnosis is confirmed by chemical analysis. The relative proportions of these felspars vary a good deal. In a rock from the Craigallian road, 2½ miles N.N.W. of Milngavie, the oligoclase is largely predominant, as also in a specimen from the Spout of the Three Marches. In rocks from the Cauldstream Burn, however, the proportions of the two felspars are more nearly equal. There are occasionally a few microphenocrysts of oligoclase, and doubtfully of orthoclase. The texture is distinctly trachytic.

The original ferro-magnesian constituent, most probably augite, was sparse and interstitial. In most of the rocks it is serpentinized, and diffused as vague green material ("viridite") throughout the groundmass. The rock of the Craigallian road, however, shows fresh augite, which, in addition to microlites, also occurs as microphenocrysts ophitically enclosing felspars. Iron ore, as magnetite and secondary hæmatite, is abundant in the mugearites. Fresh olivine has not been seen. It is probably represented by small, colourless, or reddish pseudomorphs. A notable feature of these rocks is the abundance of apatite in very thin needles.

The little late-formed patches of reddish hornblende and biotite, common in some mugearites, have been found in one rock only, the twenty-first flow of the central traverse, forming a small scarp on the S.W. side of Cochno Hill, half a mile N.W. of Cochnohill Farm. This is probably the freshest and most typical mugearite to be found in the Kilpatrick Hills. On the weathered surface it shows numerous close-set, parallel, linear rods or ribs, forming a raised pattern, and delineating a flow structure. In thin section these are seen to be due to bands

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which are somewhat coarser-grained and more felspathic than the main mass of the rock. These bands are also parallel to the close-set horizontal jointing which gives rise to the platy fissility so characteristic of the mugearites in the field. The rock contains much magnetite and a subordinate amount of colourless microlitic augite. It is devoid of olivine, a condition which has been held to favour the development of the late-formed flakes of biotite and hornblende.[46] In this rock the latter possess most of the peculiar characters described by Flett,[47] and appear to be associated with a little secondary silica in small cavities.

Since the microstructure of mugearites is trachytic, the felspar laths being more or less aligned in the direction of flow, and since the extinction of oligoclase is practically straight, a convenient test for mugearites may be devised as follows:—One of the cross-wires of the microscope is brought parallel to the flow direction of the felspar laths, the Nicols being crossed. The stage is then quickly swung round to the 45° position, when a notable and very obvious increase in the illumination of the section is the result, consequent on the majority of the felspars having been moved from the position of extinction, or near extinction, to that of greatest illumination. If, however, the trachytic texture is not well developed, or if there is a notable proportion of basic felspar, the test, of course, fails more or less completely.

Dalmeny and Hillhouse Basalts.—These types have a sparse distribution in the Kilpatrick Hills. They are found mostly in the small group of basic lavas which occurs near the middle of the succession, and are closely allied to the Dunsapie and Craiglockhart types forming that group.

A very typical Dalmeny basalt occurs as a dyke near the head of the Dualt Burn, half a mile N. of the Whangie. This contains numerous microphenocrysts of fresh, rounded olivine in a microlitic groundmass of augite, felspar, and magnetite, named in order of abundance. This may be the dyke noted by Bailey as occurring in a stream between Auchineden Hill and the Little Caldon, and containing "fresh olivine in which there has been a most remarkable and abundant separation of mag-

[46] *Mem. Geol. Sur.*, "Geology of the Glasgow District" (1911), p. 140.

[47] "On the Mugearites," *Summ. Prog. Geol. Sur. for 1907* (1908), p. 122.

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netite, evidently due to resorption or corrosion."[48] My specimen does not show this phenomenon.

Another good Dalmeny basalt occurs at the north foot of Cochno Hill in the central traverse, as the solitary representative in this locality of the basic group, conspicuous 1½ miles to the east in the district about the Black Loch. It consists of a groundmass of granular purplish augite, euhedral magnetite, and subordinate slender felspars, with rather numerous microphenocrysts of olivine verging, in some cases, on the macroporphyritic. This rock is identical with the groundmass of the Craiglockhart basalts of the Black Loch.

A rather more felspathic type comes from Tomibeg, near Muirhouses. This shows numerous small serpentinized olivines in a groundmass made up of lathy felspar, granular augite, and iron ore in approximately equal proportions. Similar rocks occur at Clober House, N. of Milngavie, and in the scarp E. of Muirhouses.

A rock midway between the Dalmeny and Hillhouse types appears as the third flow above Old Kilpatrick. Augite and iron ore are slightly in excess of the lathy fluxionally-arranged felspar in the groundmass. There are numerous microphenocrysts of serpentinized olivine, and fewer of a purplish corroded augite. In addition, sporadic macrophenocrysts of olivine, augite, and plagioclase occur, linking the rock to the Dunsapie type.

The fifth flow in the same locality is a somewhat similar rock. Augite and iron ore bulk larger in the groundmass, and the former is abundant among the microphenocrysts. There are sporadic macrophenocrysts of augite and olivine, but not felspar. The rock is therefore transitional between the Hillhouse and Craiglockhart types. The two rocks last described might be regarded as Dunsapie and Craiglockhart basalts, in which the phenocrysts are much sparser than usual.

Markle Basalts.

This type, characterized by very prominent porphyritic felspars, is perhaps the most abundant rock in the Kilpatrick Hills. It occurs in all parts, but is most abundant in the

[48] *Mem. Geol. Sur.*, "Geology of the Glasgow District" (1911), p. 138.

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upper part of the succession, and covers most of the southern and south-eastern areas.

A beautifully fresh rock, occurring as a lenticular mass, probably intrusive, between the seventh and eighth flows on Auchineden Hill, may be described as typical of this group. It is well exposed on the road of access to the Burn Crooks Waterworks, near the 880 feet O.D.[49] The groundmass, consisting of felspar, augite, and magnetite, in approximately equal proportions, is finely microlitic, all the constituents being euhedral. In this as base are set numerous macrophenocrysts of fresh felspar, and much smaller and less numerous crystals of serpentinized olivine. The felspars give extinction angles indicative of a composition Ab_1 An_1, are comparatively homogeneous, and contain numerous arranged inclusions of magnetite and augite, presenting a mechanical zoning. Some of the felspar in the groundmass, and in one slide the olivine also, becomes microporphyritic in size.

An equally fresh rock from an intrusion near Greenland Farm shows an interesting variation in the groundmass. The latter consists of abundant dark glass, which in places is full of fibrous crystallites of a brown pyroxene besprinkled and intergrown with iron ore. This carries two generations of felspars, one microporphyritic and very abundant, the other macroporphyritic and less abundant, but conspicuous in the hand-specimen. Microporphyritic olivine is represented by a few pseudomorphs in serpentine, and grains of a pale augite occur along with the small felspars. The large felspars are similar to those of the Auchineden rock above described.

Most of the Markle basalts of the Kilpatrick Hills, however, are lava flows, and these are not preserved in nearly as fresh condition as the intrusive masses described above. The mineralogical constitution remains the same, but the minerals have undergone considerable alteration. The olivines are invariably serpentinized, and the green products diffused among the other constituents, penetrating the felspars along their cleavages and other fissures. Furthermore, the porphyritic felspars frequently exhibit the patchy appearance under

[49] Tyrrell, *Trans. Geol. Soc. Glasgow*, vol xiii., pt. iii. (1909), pp. 341-2, pl. xxi., fig. 4.

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polarized light, which indicates partial albitization. This phenomenon has been fully described by Bailey and Grabham,[50] and has been attributed by them to "juvenile" reactions between the minerals and the alkaline waters which were the latest products of volcanic activity. The albitization of the felspars may thus be connected with the formation of the zeolites, which are so characteristic an accompaniment of Carboniferous volcanic activity in this area. It is noteworthy that zeolites only occur in connection with the more felspathic basalts, such as the Markle, Jedburgh, and mugearite types, and scarcely ever with rocks of the Dunsapie and Craiglockhart types.[51] Analcite is one of the commonest zeolites found in this locality. It is interesting therefore to find in the felspars of the Markle basalts of the Birny Hill small, colourless, isotropic patches having a lower refractive index than the enclosing felspar. These are in all probability to be referred to a process of analcitization analogous to the albitization described above. In some of the rocks the two processes appear to have gone on side by side, which is scarcely to be wondered at considering their chemical similarity. A difference in the amount of water present, and doubtless slight variations in physical conditions, might serve to determine whether albitization or analcitization took place, or whether one followed the other.

The fresh, probably intrusive, Markle basalt of Auchineden Hill has been analyzed for me by Mr. A. Scott, M.A., B.Sc., with the result given in Table I., col. i., p. 244. Analyses of the type Markle of East Lothian, and of a Jedburgh basalt, are tabulated for comparison.

The Auchineden analysis agrees well with the type Markle in the alkalies; but its decidedly more basic groundmass is indicated by the augmented iron, magnesia, and lime. The discrepancy between the silica and alumina percentages in the two analyses may be accounted for, perhaps, by the high summation of the Markle analysis, and by the non-determination of the titanium oxide, which probably appears in the alumina. Comparing the analysis of the Jedburgh basalt with the other two, especially the Auchineden, it will be seen that a close

[50] *Geol. Mag.* (v.), vol. vi. (1909), p. 250.

[51] *Mem. Geol. Sur.*, "Geology of the Glasgow District" (1911), p. 149.

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similarity exists between the two types. The similarity between the three analyses is further shown by their positions in the American Quantitative Classification.

Mention has already been made (p. 238) of the large group of basalts intermediate between the Markle and Jedburgh types. Transition to the Jedburgh type may take place in two ways,

TABLE I.

	I.	II.	III.
SiO_2	45·62	49·54	46·45
TiO_2	2·09	—	3·11
Al_2O_3	18·17	22·23	16·98
Fe_2O_3	1·28	9·55	3·94
FeO	8·30	1·12	8·57
MnO	·35	·08	·48
MgO	6·48	2·80	5·94
CaO	9·43	7·19	7·64
Na_2O	4·22	4·56	3·50
K_2O	1·43	1·81	1·43
H_2O+	1·54	2·42	1·68
H_2O-	·47		·24
P_2O_5	·71	—	·51
CO_2	none.	—	·41
BaO	tr.	—	nt. fd.
SrO	tr.	—	—
	100·09	101·30	100·88

I. Olivine Basalt (Markle type), *Salemose*. Road of access to Burn Crooks Waterworks, Auchineden Hill, Kilpatrick Hills. Anal. A. Scott.

II. Olivine Basalt (Markle type), *Andose*. Markle Quarry, East Lothian, F. Hatch. *Trans. Roy. Soc. Edinburgh* (1892). Vol. xxxvii., p. 119.

III. Olivine Basalt (Jedburgh type), *Andose*. Intrusion in Little Caldon Vent, Stockiemuir, Kilpatrick Hills. *Mem. Geol. Sur.* "Geology of the Glasgow District" (1911), p. 142.

by a diminution in size of the felspar phenocrysts, so that they approximate to microporphyritic dimensions, and by a diminution in their number, whereby they become sporadic and infrequent. These rocks have been grouped under the Markle type by Mr. E. B. Bailey,[52] but in the opinion of the writer

[52] *Mem. Geol. Sur.* "The Geology of the Glasgow District" (1911), p. 137.

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they are best included in the Jedburgh, since they lack the conspicuously porphyritic character which renders the Markle type so easily identifiable.

Dunsapie Basalt.

This type, characterized by abundant macroporphyritic felspar, olivine, and augite, occurs in many flows in the middle and upper part of the Kilpatrick succession. A zone of plugs and intrusions composed of this type stretches from Bowling on the west to the Drymen Road on the east. The rocks vary somewhat both in the composition of the groundmass and the relative abundance of the phenocrysts. The intrusion at Craigangawn Quarry, on the Drymen road, has a typical Dalmeny groundmass, with numerous fresh microporphyritic olivines set in a base of augite, magnetite, and felspar, named in order of abundance. In this are set rather sparse phenocrysts of olivine, purplish augite, and basic felspar. A similar groundmass occurs in the lava-form Dunsapie basalts of the Birny Hill. In other varieties, however, the felspathic constituent in the groundmass becomes approximately equal to the other constituents, and the amount of microporphyritic olivine falls off. This is correlated with an increasing abundance of phenocrystic felspar, and gradation towards the Markle type.

Felspar seems to be invariably the most abundant of the phenocrysts, so that transitions between the Dunsapie and Craiglockhart types do not occur. Usually a thin marginal band in the felspar is chemically zoned. The maximum extinction angle obtainable in the basic interior is 33°, representing a composition $Ab_1\ An_1$. On the margins, however, the composition may vary to $Ab_2\ An_1$. The felspars, in common with the augite, have suffered extensive magmatic corrosion. Many of the crystals are very irregular in shape, and have indefinite margins. They contain numerous orientated inclusions of magnetite, augite, and occasionally olivine. Augite occurs in rounded and embayed phenocrysts, almost invariably with a thin marginal zone of included magnetite. Irregular expansions of this zone occur occasionally towards the interior of a crystal, pointing to corrosive action within an embayment not far from the plane of section. It is purplish-

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brown in colour, sometimes zonal and faintly pleochroic. A central interlamellation twin is common. The augite phenocrysts are usually smaller and less abundant than the felspars.

The olivine occurs in phenocrysts ranging in size from macro- to micro-porphyritic dimensions. There is frequently an abundant microporphyritic generation. It is usually quite euhedral and unaltered, save for slight serpentinization along fissures. Where, however, alteration has taken place to any extent, the product in the Dunsapie and Craiglockhart basalts is frequently a rich red-brown, strongly pleochroic mineral with one perfect cleavage. It is often zoned with a pleochroic green serpentine, which has a similar perfect cleavage, and is charged with magnetite. The boundary between the two minerals may be extremely irregular, as though one were being formed at the expense of the other. Frequently an irregular core of the green serpentine may be found surrounded by the red mineral, and the latter has the appearance of a later product. This red lamellar mineral corresponds to what has been described as iddingsite. It is probably a ferriferous variety of serpentine (antigorite), formed by the resorption of magnetite in a green variety. It gives an extinction parallel to the cleavages, and is dichroic from a rich brown-red to dark brown or black. As in the micas the strongest absorption occurs for rays vibrating parallel to Z. From rough measurements the phenocrysts of the Dunsapie basalts, when most conspicuously developed, form somewhat less than half the total volume of the rock. As far as the porphyritic constituents are concerned, the fabric is seriate, the phenocrysts ranging in size from a millimetre to a centimetre in diameter, without any hiatus which would indicate the development of separate generations.

I am indebted to Mr. Scott for an analysis of the Dunsapie basalt of the Duncomb Hill plug. This is set out in column i. of Table II. p. 247, together with an analysis of the Dunsapie basalt of Kippie Law. The agreement of the two analyses, especially in magnesia, lime, soda, and potash, is very close.

Craiglockhart Basalt.

This type, the most basic of the group of macroporphyritic basalts, is very sparsely represented in the Kilpatrick Hills.

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The Black Loch plug and one or two lava-flows in that vicinity, and the first flow at the base of the Lang Craigs, below the Jedburgh basalts, are all that belong to this type.

The Black Loch basalts have a characteristic groundmass, consisting of granules of purplish augite and rather large grains of iron ore, with subordinate felspar in long, slender laths winding in streams between the grains. In this, as groundmass, are set numerous euhedral serpentinized olivines, mostly of

TABLE II.

	I.	II.
SiO_2	45·10	46·01
TiO_2	2·66	—
Al_2O_3	15·04	19·19
Fe_2O_3	8·85	5·91
FeO	4·62	6·75
MnO	·45	·19
MgO	6·68	6·81
CaO	8·71	8·68
Na_2O	3·78	3·27
K_2O	1·04	1·20
H_2O+	1·76	3·07
H_2O-	1·31	
P_2O_5	·56	—
CO_2	none.	—
BaO	p.n.d.	—
SrO	·04	—
	100·60	101·08

I. Dunsapie basalt (*Camptonose*), Duncomb Hill, Kilpatrick Hills. Anal. A. Scott.

II. Dunsapie basalt (*Andose*), Kippie Law Quarry, E. Lothian. Anal. J. S. G. Grant Wilson; Hatch, *T.R.S.E.* Vol. xxxvii. (1892), p. 118.

microporphyritic size, but others ranking as small phenocrysts. At one place in a slide the olivines are crowded together with a little granular augite, to the entire exclusion of felspar. This aggregate is about ¼ inch in diameter, and appears to be a kind of olivine nodule. It partly encloses one of the augite phenocrysts. The latter, which have the same characters as those of the Dunsapie basalts, are less numerous than the olivines, but larger in size. In places several crystals are joined

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together with a little olivine to form a glomero-porphyritic group.

The flow at the base of the Lang Craigs has a much more felspathic groundmass than the above, and in this respect conforms to the association in which it is found. It might be regarded as a Dalmeny basalt (abundant microporphyritic olivine), with the addition of large phenocrysts of augite.

Petrology.

(a) *Morphology.*—By far the greater portion of the igneous rocks of the Kilpatrick Hills consists of tabular masses, usually long in comparison with their thickness or width. These are gently tilted lava-flows ejected from the numerous vents lining the northern edge of the plateau, or piercing the plateau itself. These flows range from 20 to 200 feet in thickness, and form terraces of corresponding thickness, which have been worn back by denudation along the junction of contiguous flows. Each flow is slaggy, vesicular, or amygdaloidal at top and bottom, but towards the centre passes gradually, except in very thin masses, into a fine-grained holocrystalline rock, which may be taken as the petrographic type of the flow. The wearing back of each flow takes place along the plane of weakness developed where the slaggy rock at the top of one flow and at the bottom of the next overlying come together. The hard, unaltered central portion of each flow stands up as a more or less vertical cliff of bare rock at the back of each terrace. Some of the thicker flows are traceable for several miles, but it is not usual for a flow to extend more than 1 or 2 miles in any direction. A noteworthy example of diminishing thickness and ultimate disappearance of flows is seen near the Lily Loch, to the E. of Duncomb.

Intruded between the flows are a few sills, as at Auchineden Hill and Greenland Farm; but the mass of the intrusions occur as plugs in the vents, and may or may not be accompanied by fragmental materials. Furthermore, a not very abundant dyke-phase is developed in the sandstones about the northern margin of the Kilpatrick plateau, usually in the neighbourhood of the vents. They are absent from, or at least have not been found in, the lavas.

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In the Kilpatrick Hills, therefore, and, indeed, in the whole Clyde plateau, there is abundant representation of the effusive phase of igneous activity, much less of the phase of minor intrusion, and none at all of the deep-seated plutonic or abyssal phase. The latter may be assumed to be in existence, but still buried deeply. The products of the effusive and hypabyssal phases are substantially identical.

(b) *Mineralogical and Chemical Characters.*—The suite has no outstanding mineralogical characteristics. The number of minerals is small, and their range of combination restricted. The minerals of invariable occurrence are plagioclase, ranging from oligoclase in the mugearites to bytownite in the Dunsapie basalts; augite, sometimes a pale diopside-like variety, but more usually maroon or purplish in colour and pleochroic; olivine, frequently decomposed to serpentine and iddingsite; and magnetite. Minerals of variable occurrence are orthoclase, apatite, ilmenite, hornblende, and biotite (in the mugearites only). Albite and rarely analcite occur as pneumatolytic products in the felspars, and in this connection the abundance of zeolites in the Kilpatrick Hills should be mentioned. As regards texture, taking rocks from the centres of the flows as the petrographic types, the great majority of the rocks are holocrystalline, whilst fine-grained and megascopically aphanitic. The fabric may or may not be porphyritic. In the latter case distinct generations of phenocrysts are not common—the phenocrysts are seriate, not hiatal, in size, ranging from crystals 2 millimetres up to 2 centimetres in length.

As a series, the rocks of the Kilpatrick Hills are basalts ranging from comparatively acid varieties, such as mugearite (oligoclase basalt) to rocks verging on the ultrabasic, such as the Hillhouse and Craiglockhart types. They form a practically continuous series, the various types of which are distinguished not so much by their differences in mineralogical composition as by variations in the proportions of a small group of minerals. The chemical composition of the Scottish Calciferous Sandstone basalts is illustrated by a series of selected analyses in Table III. In the microporphyritic basalts, Nos. i.-v., the analyses show uniform gradations and relationships amongst various constituents. With silica increasing gradually from 40 to

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50 per cent., the iron oxides remain practically stationary, whilst magnesia and lime show a gradual decrease and the alkalies a gradual increase. These gradations may be better correlated with the mineralogical variations, and a better idea of their significance obtained, if the analyses are calculated into

TABLE III.

	I.	II.	III.	IV.	V.	VI	VII.	VIII.
SiO_2	40·2	42·49	46·45	50·06	50·29	45·62	45·10	46·28
TiO_2	2·9	2·51	3·11	2·46	1·67	2·09	2·66	2·06
Al_2O_3	12·8	13·85	16·98	15·72	18·11	18·17	15·04	14·18
Fe_2O_3	4·0	2·59	3·94	3·94	4·09	1·28	8·85	3·79
FeO	10·4	9·32	8·57	7·63	8·06	8·30	4·62	7·34
MnO	—	·29	·48	·30	·65	·35	·45	·09
(CoNi) O	—	·09	nt. fd.	·03	nt. fd.	—	p.n.d.	·05
MgO	11·9	11·21	5·94	3·82	3·32	6·48	6·68	10·82
CaO	10·4	9·76	7·64	5·90	1·76	9·43	8·71	9·88
Na_2O	2·7	2·39	3·50	4·55	5·06	4·22	3·78	2·58
K_2O	·8	·87	1·43	2·16	2·65	1·43	1·04	1·01
H_2O at 105° C.	3·4	·47	·24	·67	·86	·47	1·31	·31
H_2O above 105° C.	(ignit.) 3·35	1·68	1·36	3·45	1·54	1·76	1·66	
P_2O_5	—	·61	·51	·64	·44	·71	·56	·44
CO_2	—	·22	·41	1·08	nt. fd.	none.	none	nt. fd.
Cl	—	—	—	·04	—	—	—	—
BaO	—	.04	—	·03	nt. fd.	tr.	p.n.d.	nt. fd.
FeS_2	—	—	—	—	·06	Sr.O (p.n.d.)	SrO ·04	—
	99·5	100·06	100·88	100·39	100·41	100·09	100·60	100·49

I. Nepheline Basalt ("Limburgite" of Hatch), *Limburgose*, Chester's Quarry, East Lothian. Hatch, *T.R.S.E.* (1892), vol. xxxvii., p. 116.

II. Hillhouse Basalt (*Auvergnose-Camptonose*), Hillhouse Quarry, near Linlithgow. *Mem. Geol. Sur.*, "Geology of the Glasgow District" (1911), p. 142.

III. Jedburgh Basalt (*Andose*), intrusion in Little Caldon Vent, Stockiemuir, Kilpatrick Hills. *Ibid.*, p. 142.

IV. Basaltic Mugearite (*Andose-Akerose*), lava, hilltop, ½-mile N. by E. of Balhennan Farm, Fintry Hills. *Ibid.*, p. 142.

V. Mugearite, lava (*Akerose*), 500 yards S., 30° W. of cairn on Lairs, above Lennoxtown. *Ibid.*, p. 142.

VI. Markle Basalt (basic type) (*Salemose*), Auchineden Hill, Kilpatrick Hills. Anal., A. Scott, M.A., B.Sc.

VII. Dunsapie Basalt (*Camptonose*), Duncomb Hill, Kilpatrick Hills. Anal., A. Scott.

VIII. Craiglockhart Basalt (*Camptonose-Auvergnose*), S.E. of Redside, 1¼ mile N.N.-W. of Whitekirk, Haddingtonshire. *Mem. Geol. Sur.*, "Geology of East Lothian" (1910), p. 121.

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the "norm" or standard mineral composition of the American Quantitative Classification.[53] The "mode" or actual mineral composition would, of course, be better for purposes of comparison were it obtainable with any degree of accuracy. In this series of rocks, however, the mode is "normative," that is, the calculated standard mineral composition corresponds closely to the actual composition. Quite apart from their use as the basis of the American Quantitative Classification, the norms may be extremely useful as a means of comparing analyses, often bringing out relationships which are not apparent in the ordinary statement of the analyses.[54] The norms of the analyses i.-v. in Table III. are collected in the same order in Table IV. below—

TABLE IV.

		I.	II.	III.	IV.	V.
S.	Orthoclase	5·00	5·56	8·34	12·79	15·57
	Albite	3·14	13·10	29·34	38·25	42·44
	Nepheline	10·79	3 94	—	—	—
F.	Corundum	—	—	—	—	4·90
	Anorthite	20·02	24·19	26·69	16·12	5·56
	Diopside	25·42	16·52	6·31	7·72	—
	Hypersthene	—	—	2·19	3·55	15·06
	Olivine	20·48	22·65	12·67	6·87	2·20
	Magnetite	5·80	3·71	5·57	5·57	6·03
	Ilmenite	5·47	4·71	5·93	4·71	3·19
	Apatite	—	1·34	1·34	1·34	1·01
S/F. Ratio		·25	·31	·62	1·08	1·53

Of this list of minerals, corundum and hypersthene do not occur in the rocks. The constituents of the hypersthene are probably bound up with the diopside to form the augite actually present in the series; whilst the corundum, due to an excess of alumina over that necessary to build the felspars, is probably also actually to be found in the augite.

Following a suggestion of Dr. Evans,[55] the anorthite and normative corundum have been treated as belonging to the

[53] Cross, Iddings, Pirsson, Washington. "Quantitative Class. of Ign. Rocks." Chicago, 1903.

[54] W. Cross. *Q.J.G.S.*, vol. lxvi. (1910), p. 495.

[55] *Q.J.G.S.*, vol. lxvi. (1910), p. 504.

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femic group of the standard minerals. This mode of arrangement has been found to give much better results in the ensuing discussion than if the above minerals had been included, as in the Quantitative Classification, with the salic group. Under this arrangement the ratio of the two groups into which the standard minerals are divided is called the "S/F ratio," in order to distinguish it from the Sal/Fem, on which the Quantitative Classification is based.

It will be noted that in the microporphyritic series (i.—v.)the S/F ratio gradually increases from the nepheline basalt to the mugearite. Along with this orthoclase and albite show a similar gradual increase. The other constituents, however, show more complex relations, which are brought out beautifully when the figures are plotted as ordinates in a variation diagram against the S/F ratios as abscissæ (Fig. 2). It will be seen from the diagram that, whilst the plagioclase felspar increases in amount until the Jedburgh basalt is reached, its composition becomes increasingly alkaline. From the Jedburgh basalt to the mugearite, however, the amount remains constant, whilst the alkalinity rapidly increases. The curves thus bring out clearly the increasing content of alkali-felspar in the mugearitic rocks. Towards the mugearite end of the series olivine diminishes rapidly, whilst orthoclase and pyroxenes increase. The diagram thus shows very concisely the relations between the mineral constituents established empirically by microscopic examination, and gives them a quantitative basis. The regularity of the curves serves to demonstrate not only that the classification of the basalts is based on a true principle, but that the S/F ratio is here valid, whatever its value may prove to be in other series of analyses.

It should be remarked that an equally good series of curves could be got were the first analysis, that of the nepheline basalt of Chester's Quarry, deleted. This and others of the same group are mainly intrusive sills; and whilst some may be connected with Calciferous Sandstone volcanicity, it is probable that others belong more particularly to epochs of igneous activity later than the Calciferous Sandstone.[56]

If an analysis of a Dalmeny basalt were available, it would

[56] G. W. Tyrrell, *Geol. Mag.* (v), vol. ix. (1912), p. 130.

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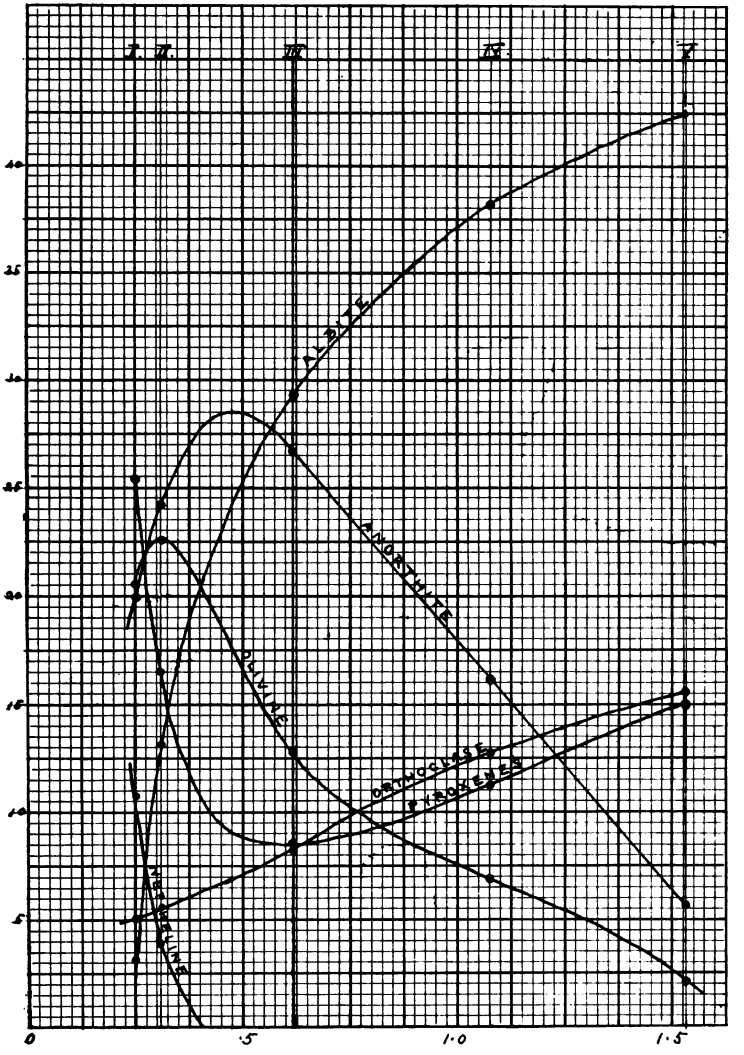

Fig. 2.

Variation-diagram of the Microporphyritic Basalts of the Scottish Carboniferous.

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doubtless fit into its proper place in the diagram between the Jedburgh and Hillhouse basalts.

(c) *Order of Succession and Grouping of the Lavas.*—Whilst a fairly definite order of succession has been made out in the Campsie and Kilsyth Hills, the attempt to find such an order in the Kilpatrick Hills has failed. Only very general statements can be made, such as that Jedburgh basalts are more abundant towards the base of the succession, Markles and mugearites towards the top, and the basic basalts, Craiglockhart, Dunsapie, and Dalmeny, near the middle.

In order to determine the order of succession, four traverses were made across the Kilpatrick Hills—(1) Western traverse—from the Lang Craigs, near Dumbarton, *via* Craigarestie and the Haw Craig, to Old Kilpatrick; (2) Central traverse—from the Thief's Hill, *via* Lily Loch, Craighurst, and Cochno Hill, to Duntocher; (3) Eastern traverse—from Burn Crooks, *via* Kilmannan Reservoir and Black Loch, to Douglas Muir; (4) Auchineden traverse—from the Whangie, in a south-westerly direction, across Auchineden Hill to the Burn Crooks Waterworks road. Beyond this point the escarpments cease to be distinguishable. The results of these traverses are tabulated in parallel columns below, together with the order of succession as determined in Campsie Glen.[57] It is not intended to convey an idea of a strict contemporaneity for the flows which are found in juxtaposition in this table. It will be noted that the great basal Jedburgh basalt group of Campsie Glen remains fairly recognizable up to the eastern traverse, but towards the western part of the Kilpatrick Hills it does not so much disappear as it becomes heterogeneous by the intercalation of other types. The Jedburgh type remains a prominent feature in the central and western traverses, especially the latter. The central traverse is distinguished by abundant alternations of Markle basalt and mugearite. The more basic basalts, Dalmeny, Hillhouse, Dunsapie, and Craiglockhart, make their appearance from about the middle of the succession, and occur at intervals to the top, but are not sufficiently homogeneous to constitute a group. If a grouping be attempted at all in the Kilpatrick Hills, it will be into a lower group of Jedburgh,

[57] *Mem. Geol. Sur.* "Geology of the Glasgow District" (1911), p. 100.

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Western Traverse.	Central Traverse.	Eastern Traverse.	Auchineden Hill.	Campsie Glen.
29-31 Jedburgh.	22 Markle.	Escarpments indistinct towards top.	Escarpments indistinct towards top.	31-33 Markle.
27-28 Dunsapie.	21 Mugearite.	Mugearites at Craigton; Dalmenys at Muirhouses and Clober.	Dunsapies at Blair's Hill, Boards, and Dykehouse, near Blanefield.	30 Mugearite.
26 Jedburgh.	20 Markle.	22 Dunsapie.	Markles at Craigmaddie and Deil's Craig Dam.	29 Albite—Keratophyre.
25 Craiglockhart.	19 Mugearite.	20-21 Markle.	Mugearites and Markles, S. of Craigallian, and at Mugdock.	28 Jedburgh.
24 Hillhouse.	18 Markle.	18-19 Dunsapie.	14 Markle.	27 cf., Mugearite.
23 Jedburgh.	17 Jedburgh – Mugearite	17 Markle.	13 ? Thin, slaggy flow.	26 Markle.
22 Dalmeny.	16 Mugearite.	16 Jedburgh.	12 Jedburgh—Markle.	25 Mugearite.
21	15 Markle.	15 Craiglockhart.	10-11 Jedburgh—Mugearite.	23-24 Markle.
20 Dalmeny—Jedburgh	14 Jedburgh—Mugearite	14 Markle—Jedburgh.	9 Jedburgh—Markle.	22 Jedburgh – Mugearite.
18-19 Markle.	13 Jedburgh.	13 Craiglockhart	8 Markle.	21 Jedburgh.
16-17 Jedburgh.	12 Dalmeny,	8-12 Markle.	7 Jedburgh—Mugearite	20 Jedburgh—Mugearite.
14-15 Dunsapie,	11 Jedburgh—Markle.	2-7 Jedburgh.	6 Jedburgh.	19 Decomposed Porphyritic.
13 Jedburgh—Markle.	10 Markle.	1 Jedburgh—Mugearite	5 Jedburgh—Mugearite	18 Markle.
9-12 Jedburgh.	7-9 Jedburgh—Markle.		4 Jedburgh.	1-17 Jedburgh.
8 Mugearite.	6 Jedburgh.		3 Jedburgh—Dalmeny.	
7 Jedburgh—Mugearite.	5 Mugearite.		1-2 Jedburgh.	
5-6 Jedburgh.	4 Markle.			
4 Markle—Jedburgh.	3 Mugearite.			
3 Jedburgh.	2 Markle.			
2 Jedburgh—Dalmeny	1 Mugearite.			
1 Craiglockhart				

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Markle, and mugearite basalts, devoid of phenocrystic olivine and augite; and an upper group, still containing the same types, but with the addition of intercalations of basalts rich in olivine and augite. Such a division, however, is too vague to have any genetic significance.

The sequence in the eastern part of the Kilpatrick Hills is given in the "Glasgow Memoir" as follows:—(1) Jedburghs (Auchineden Hill), (2) Markles with mugearites, (3) Craiglockharts and Dunsapies (Black Loch), (4) mugearites and Markles (Strathblane and Craigton districts). These represent the varied assemblage of the upper part of the Campsie succession,[58] and the grouping here given corresponds well with the eastern traverse. No divisions of general application, however, can be profitably made in the Kilpatrick Hills, as will be seen on comparing the various traverses.

Intrusions and Vents.

Intrusive rocks are comparatively sparse in the Kilpatrick Hills, and are usually associated with or found in the vents. The general character of the latter is fully dealt with in Sir A. Geikie's "Ancient Volcanoes of Great Britain," and several of the principal vents in the Kilpatrick Hills are described.[59] It is unnecessary, therefore, to describe them here in detail. Most of the intrusive rocks are in the nature of plugs sealing up vents, or as irregular protrusions into the agglomerate partly filling a vent. The plugs stand up as steep, conical hills rising abruptly from the general level, whether of lava or sedimentary rock, and clearly have a circular or elliptical cross-section and a cylindrical form, with vertical contacts. Typical examples are found in the group of vents forming Duncomb and Fynloch, the highest points in the Kilpatrick Hills. Where the vent is composite, containing both agglomerate and massive igneous rock, the form, whilst outstanding, is apt to be rather less regular than that of the plugs. A typical example is Dumbuck, between Bowling and Dumbarton. Sills are very

[58] *Mem. Geol. Sur.* "Geology of the Glasgow District" (1911), pp. 99, 101-2.

[59] Vol. i. (1897), pp. 394-406. See also the *Glasgow Memoir* (1911), pp. 104-109.

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sparse; a sill-like intrusion occurs near Greenland Farm and Auchentorlie, near Bowling, but this passes into a plug-like mass near the Clyde at Dunglass Castle. It is possible that some of the shorter, thicker, and fresher escarpments in the lava plateau are due to intrusive rocks.[60]

The majority of the plugs and vents are distributed along the northern front of the Kilpatrick Hills from Dumbarton to the Little Caldon; and, just as in the similarly distributed vents of the Dumgoyn group in the Campsie Fells, they are composed mainly of Jedburgh basalts. Some of the intrusive rocks near Dumbarton, notably that of Dumbuck Hill, are transitional to the Dalmeny type. This group of vents and plugs pierce the sedimentaries immediately to the north of the lava escarpment.

In the lava plateau itself occurs a group of plugs and intrusions consisting mainly of macroporphyritic basalts. These are distributed in two lines, one running from Bowling to the Kilmannan Reservoir, and the other from the Black Loch eastward. The intrusive mass of Auchentorlie is a fresh Markle basalt (Greenland Farm, p. 242); that of the Hill of Dun is a Dunsapie.[61] There are four plugs about Duncomb and the Fynloch, not three, as on the 1-inch Geological Survey map, sheet 30. Three of these—Duncomb itself, Middle Duncomb, and Little Duncomb—consist of beautifully fresh Dunsapie basalts; the fourth, Fynloch Hill, is a fresh Jedburgh. About a mile to the east of Duncomb occurs a plug-like mass of Jedburgh basalt, called Dennistoun's Craig on the 6-inch quarter-sheet, and unmarked on sheet 30 of the 1-inch map of the Geological Survey. Still further to the east, on approximately the same horizon, occurs the possible Markle intrusion of Auchineden Hill (p. 242). The Black Loch plug is a Craiglockhart basalt. At High Craigton, on the same horizon, occur three small intrusive masses, two of which are Dunsapie basalts, and the third a Markle.[62]

Broadly speaking, the distribution of the vents coincides with that of similar types amongst the lavas. The volcanic activity originated along the line of Jedburgh vents, which, in view of

[60] Tyrrell, *Trans. Geol. Soc. Glasgow*, vol. xiii., pt. iii., p. 342.

[61] Teall, *Brit. Petrog.* (1888), p. 193.

[62] *Glasgow Memoir* (1911), p. 111.

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the disproportion of Markle and mugearite vents to the abundance of those rocks amongst the lavas, probably also produced the Markle and mugearite basalts associated with the Jedburghs. Later the vents migrated to the south-east, piercing the lava plateau, and were filled with the macroporphyritic basalts which constitute most of the middle and upper portion of the sequence. It is possible that some of the older vents were still erupting at this time, and produced the Jedburgh basalts intercalated in the upper part of the sequence. The interdigitation of numerous different flows from neighbouring vents erupting diverse materials is responsible for the lack of order in the succession of the lavas.

Small dykes occur sparingly in the sandstones along the line of the Jedburgh vents. They are mostly fresh Jedburgh basalts, but one, in the Dualt Burn (p. 240), is a Dalmeny type.

The large vents of the Meikle Bin type, characterised by their size and by a great abundance of dykes, not only of basalts, but also trachytes and felsites, are not represented in the Kilpatrick Hills. In the continuation of the plateau to the west of the Clyde a great Meikle Bin vent rises in the Misty Law district, and it is probable, judging from the nature of the dykes of the Cumbraes, that a similar vent is buried beneath the waters of the Firth in that vicinity.

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No. X.—The Sandstones of the Upper Red Barren Measures to the East of Glasgow.

By William R. Smellie, M.A., B.Sc., Baxter Demonstrator in Geology, Glasgow University.

[Read 15th February, 1912.]

Introduction.

The Upper Red Barren Measures cover an area of considerable extent and of vast economic importance, occupying at the one time the heart of the mining district and the centre of the Glasgow Basin. They occur mainly as one uninterrupted mass in the Uddingston district, extending N. and S. for 8 miles and E. and W. for 6 miles. Scattered around this main mass are several small outliers, the chief one on the north side being bounded by the east-and-west fault at Shettleston, and on the south side the main outlier is bounded by the east-and-west fault at Rutherglen. They attain their maximum thickness in the Uddingston district (roughly 800 feet in the Hallside Colliery), and overlie the Productive Coal Measures without unconformity, the position of Skipsey's Marine Band being taken as the line of demarcation. The lower half of the Barren Measures consists of sandstones, shales, and fireclays, with occasional thin seams of coal and cream-coloured limestone. The upper part, with which this paper deals, consists mainly of massive Red Sandstone. Historically they are interesting both to the geologist and to the student of the economic development of the land they occupy, for prior to 1840 they were considered to be Old Red Sandstone. The men who corrected this error have left no record of their work, so that we are in ignorance of the methods by which they arrived at their conclusions.

These sandstones occupy the level plain about the Clyde, and, having a plentiful supply of overburden, boulder clay, and alluvium, they are exposed in few good natural sections, so that here again the geologist is dependent on the quarryman for facilities of study. The Bothwell Park Quarry is the most suitable in the area. It is large and extensive, exhibits most

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of the types of rock to perfection, and is convenient to an old exposure, Bell's Quarry, which dates back two hundred years, and thus is valuable for studying the weathering.

Types of Rock.

In the quarries the sandstone is exposed in many large vertical faces, invariably red, so that at first sight the deposit appears to be massive and uniform. On chipping with the hammer it is found that fresh surfaces appear very much lighter in colour, and it is evident that there are varieties of the rock. The rock at the top, which may be called the White Top Rock, is almost white when fresh. Beneath this come bands of micaceous sandstone, sometimes not more than a few inches thick, but persisting at a fairly constant horizon. These pass down into a very fine-grained, finely bedded sandstone, below which comes the Liver Rock, which is grey to liver coloured, and well bedded. All types possess in common the peculiar property of assuming a deep red colour on being subjected to friction. The same colour is taken on on weathering, and is due to the spreading of the little grains of hæmatite.

The White Top Rock.—This is an even-grained, false-bedded sandstone composed of particles averaging ·25 mm. diameter. Ordinarily the bedding is little seen, but in places limonite staining has worked along the planes of sedimentation, exhibiting the bedding with artificial brightness. Along joints, however, the limonite more often stains the stone without any relation to the bedding planes. A thin section (Fig. 3, at end) shows this sandstone to be composed of interlocking, angular, and sub-angular grains of quartz and felspar, with fairly common muscovite and very occasional biotite. The cementing materials are plentiful in number, but greatly lacking in quantity. Hæmatite is the most common cement; it does not coat the particles in a thin film, as in the New Red Sandstones, but occurs as small botryoidal grains unevenly distributed, and occasionally as larger areas replacing some mineral grain. Secondary silica is present to some extent, as is shown by the remarkable manner in which some of the irregular quartz grains fit each other. Low-polarising aggregates of kaolinite occur distributed very irregularly, and act as a third cementing material.

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Lastly, calcite, though often absent, is found in minute quantities in this rock. In spite of this formidable array of cements, the stone is found to have as much as 22 per cent. of interspaces, so that it is very friable, and lacking in mechanical strength. Its sp. gr. is 1·94.

The Liver Rock.—The description of the White Top Rock applies also to the Liver Rock, with the following important differences:—The White Top Rock may be considered to be composed of one size of particles averaging ·25 mm. diameter. The Liver Rock, on the other hand, is composed of particles of two distinct sizes—(*a*) ordinary particles like those of the White Top Rock, ·25 mm. diameter; and (*b*) particles of a larger size ranging up to ·9 mm. in diameter. Also, cementing material, especially hæmatite, is more abundant. The two sizes of particles is a repetition of the old case of the cannon balls and the small shot, and this, together with the increase of cement, has the effect of reducing the interspaces, which are only 18 per cent., as compared with 22 per cent. in the White Top Rock.

The Sandstone as a Building Stone.—Since the two foregoing types are the only two of economic importance, it might be well to digress here to consider their value as building stones before going on to the other types of rock. Analyses[1] show them to have the following constitution:—

CHEMICAL ANALYSES.

White Top Rock.			Liver Rock.		
Free Silica,	81·87	93·37	Free Silica,	80·12	91·23
Silicates,	11·50		Silicates,	11·11	
Iron (as Hæmatite),	2·34		Iron (as Hæmatite),	2·81	
CaO	1·47		CaO	2·47	
Al_2O_3	1·46		Al_2O_3	1·09	
Water,	·94		Water,	·58	
CO_2	A Trace.		CO_2	1·70	
	99·58			99·88	
Sp. Gr.	1·94		Sp. Gr.	2·21	

From a consideration of the chemical analyses it would appear that these stones should be good weather stones, the noticeable points being the complete absence of carbonate from

[1] The analyses have been made by Mr. A. Scott, M.A., B.Sc.

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the White Top Rock and the very small quantity present in the Liver Rock. Going on the quantity of carbonate present as the criterion of a good weather stone (as is done by most architects), the White Top Rock would be considered superior, but consideration of chemical analyses alone is quite inadequate evidence to base an opinion on. However, when we add the thin section under the microscope, and an examination of quarry faces and buildings which have been exposed to time and weather, then the equipment is complete. The main constituents of the rock are quartz, felspar, and muscovite, with cements of hæmatite, quartz, kaolinite, and carbonate. As can be seen from the chemical analyses there are practically 80 per cent. quartz and 10 per cent. felspar. Felspar is a source of weakness in some sandstones but here it is no drawback whatever, for the felspars are almost all perfectly fresh, and the majority are potash felspars, chiefly microcline and orthoclase, although some of the soda-lime plagioclases have been recognised also. The other and most fruitful source of weakness in a sandstone is the cement, carbonate being least desirable. This is where the White Top Rock would appear to score off the Liver Rock, but the microscope shows the reverse to be the case. The Liver Rock possesses all the advantages of the other, and, in addition, has two sizes of grains and a little carbonate, which reduce the pores, and make the rock more compact and coherent. This renders the stone less liable to disintegration mechanically by percolating water and frost, so that this is exactly the exceptional case where the presence of carbonate is rather advantageous than otherwise. None of the other constituents of the rock are at all vulnerable to the attacks of the acid atmosphere of cities.

Examination of buildings confirms the evidence of chemical analysis and thin section, and in this connection a very fortunate chance presents itself—up the dip of the rock from the Bothwell Park Quarries, and about 300 yards distant, the face of an old quarry is exposed. This is Bell's Quarry, which was opened two hundred years ago, so that here we have the actual stone at present worked in the neighbourhood exposed for a known time. Such an exposure is much more useful for the present

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purpose than the fine exposures along the banks of the Clyde at Bothwell Castle, for there the rock is on a higher horizon, being nearer the centre of the basin, and it is a different type. Further, it has been exposed for an indefinite period, is an inferior weather stone, and has not been worked for many years. To return to the two-hundred-years-old exposure, examination shows this old face still bearing the pick marks of the quarrymen, still plane and regular, and weathering excellently in spite of the fact that it is situated in a district ringed by coal mines and steelworks, which render the atmosphere scarcely less hurtful than that of a city. To good weather qualities the stone adds facility in quarrying, and therefore cheapness, another very desirable quality.

The main disadvantage of the stone is its colour. The cementing hæmatite is present as little botryoidal aggregates, and this gives the rock a dull uncertain tint, neither so bright nor so uniform as the sandstones of the Permian and Trias. Again, the presence of kaolinite cement and fairly numerous pores detract from the mechanical strength of the rock, so that it would not give an exceptionally high crushing test. This is not of vital importance for ordinary building purposes, however, for there the strains involved are usually well within the limit that the stone can bear. The sandstone is subject to various irregularities, which will be dealt with later. These, however, are easily seen, and have simply to be avoided in the stone selected for building purposes. Quarrymasters in this area, as in others, deplore the modern practice of building on "cant," which has been extensively adopted for cheapness. All freestones should be built on their natural bed, but building on "cant" removes the stone from its natural bedding position, thus seriously impairing its weather qualities, shortening its life, and detracting from its reputation as a building stone.

Flaggy Bands in the Sandstone.—Between the White Top Rock and the Liver Rock bands of very micaceous, flaggy sandstone occur. They are present elsewhere, but are more persistent at this horizon. In the Bothwell Park Quarry they are only a few inches thick, and differ from the rest of the rock only by having a much larger proportion of mica, but when followed for a few hundred yards to Bell's Quarry they have

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thickened out to about 10 feet of very fine, incoherent red shale. Rapid lateral variation in the type of sediment such as this seems common in the area. Thin sections of these flaggy sandstones are most fascinating, and a casual examination might easily lead one to believe that the slide had been made from a Dalradian quartz-mica schist. There is a marked parallel orientation of all constituents. Quartz makes up the bulk of the slide, fresh felspars are not uncommon, and mica occurs in large plates, muscovite and biotite intergrown and bending round the other constituents in true schist fashion. The particles are cemented in the usual manner of the sandstones, so that here the pseudo-schist aspect is lost. In places the quartz and felspar grains become so reduced as to leave bands composed mainly of layer after layer of mica in large plates, ranging up to 2 or 3 mm. across, just as if they had been blown into a temporarily isolated pool, and allowed to settle there. The presence of these micaceous bands and minor stratifications seriously affects the weathering of the stone in which they occur, and an excess of this fine material, together with occasional aggregates of it, produce a kind of honeycomb weathering well seen in the exposures along the Clyde at Bothwell Castle and Priory. Building stone quarried from this horizon is a very poor weather stone, the Castle, the Priory, and Bothwell Parish Church being outstanding monuments to its inefficiency.

Irregularities in the Rock.

Clay Galls.—Throughout the whole depth of the sandstone clay galls are occasionally met with. These are most commonly about 1 inch in diameter, but are got varying in size up to several feet, when they become lenticular in shape. The clay is very fine, usually purplish red, but occasionally light green. They are scarce, quite irregularly distributed, and of all sizes, so that their presence there seems best accounted for by considering them samples of late Carboniferous soil dropped there from the roots of drifting snags.

Whinnyboles.—The most frequent and conspicuous irregularity in the sandstone is what the quarrymen term "whin"

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These whinnyboles are very common in the White Top Rock at a certain horizon, and become scarcer and smaller deeper down. They quite unaccountably assume a variety of sizes and shapes, ranging from small nodules weighing ounces to large masses weighing tons, and from perfect spheres to weird masses which assume an infinite variety of fantastic shapes. The colour is a deep red or purple, and the rock is much harder, more compact, and more uniform than the ordinary sandstone. When chipped with the hammer it sometimes breaks along plane, glistening surfaces, as if all the varied material of which it is composed were ophitically enclosed in calcite, although calcite is not present in any appreciable quantity. A thin section (Fig. 2) shows the whin to be composed of grains averaging ·4 mm. in diameter, and of very varied shape, set in a plentiful and continuous cement showing deep red in reflected light, so that a large percentage of hæmatite might be expected. However, an analysis shows the whin to have the following composition:—

Free SiO_2	49·61
Silicates	11·38
Al_2O_3	1·27
MnO	10·70
Fe_2O_3	7·15
CaO	13·35
MgO	5·11
Loss	2·32
	100·89

Jointing.—The sandstone is traversed by a series of plane joints or "backs" running in a north and south direction. Another series, less often present, cut the first at an angle of 60°, running, roughly, N.W. The fine material of the overlying boulder clay has been washed down these joints, forming a quite appreciable coating. Occasionally huge masses of the rock are found possessing a spherulitic jointing. This is the most imposing structure met with, and is quite inexplicable, for there is no whinnybole nucleus, nor is there any appreciable difference in the strength of the cement of the different layers. The plate shows the structure well (Fig. 4).

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Mineralogical Constitution.

The sandstone has yielded a rich series of minerals which are not only interesting in themselves, but are valuable, as indicators of the source of the material and as reconstructors of late Carboniferous topography. The minerals have been recognised mainly by the thin section and by heavy liquid separation. Thin sections of a friable sandstone such as this give infinite trouble to prepare, requiring the chip to be well boiled in balsam before grinding. The sections, however, have been found most useful in this case, though the contrary has often been stated. The cement, the grains, and the inclusions can all be studied much better than is possible with loose grains.

Heavy Liquid Separation.—The majority of the minerals found were got in heavy residues. The method employed was as follows:—A weighed quantity (about 40 grams.) of the sandstone was disintegrated carefully so as to detach the grains without fracturing them. The sand was treated with strong HCl to clean the grains, the clay substance being poured off, dried, and examined. When the grains were free from colouring matter the sand was dried and passed through bromoform (sp. gr. 2·85), Smeeth's separator being used. Bromoform has been objected to on the ground that it gives imperfect separations owing to the facility with which convection currents are set up. In all the separations carried out this difficulty was only encountered twice, once when the sand was added before it was quite cool, and a second time when the apparatus was at a window under a strong sun. Otherwise the bromoform served excellently, but required almost continual stirring. After the separation the heavy residue was weighed and mounted. Some of the light residue was mounted also to be used for examining the size, shape, and inclusions of the grains. At first an attempt was made to use the percentages of heavy residues, from specimens collected from different localities, to give the direction of the currents and an indication of the source of the material, the argument being that the heavy minerals would be more plentiful as the source was approached. Samples collected from most of the

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exposures in the area were treated, and in the main these showed higher percentages towards the north and west, affording, apparently, good evidence in support of the other indications pointing to that source. However, Professor Gregory cast doubts on the value of this evidence, quoting the case of the irregular distribution of fine gold in placers, and advising further investigation. To this end a series of samples were collected over a vertical range of 90 feet from a suitable face in the Bothwell Park Quarries, specimens being taken every 10 feet. The residues were found to vary from ·04 per cent. to ·81 per cent., and that, too, quite irregularly, there being no regular vertical increase or decrease. This alone, without considering lateral variation, renders percentages valueless in this case, for the sandstones occupy the centre of a basin, and, in the few exposures available, the horizon could not be determined to within much more than 10 feet. This complete failure of percentages does not detract from the value of the heavy minerals themselves, and since it entailed the mounting of many heavy residues, many minerals were available for examination. The same suite of minerals was present in all the residues, though the relative proportions varied.

Cubic System.	*Tetragonal System.*
Iron Pyrites.	Zircon.
	Rutile.
	Anatase.
Orthorhombic System.	*Hexagonal System.*
None.	Quartz.
	Tourmaline.
	Hæmatite.
	Ilmenite.
	Calcite.
Monoclinic System.	*Triclinic System.*
Muscovite.	Microcline.
Biotite.	Plagioclase Felspars.
Orthoclase.	
Kaolinite.	
Chlorite.	

The above list of minerals includes only those continually present or of special importance, and does not profess to be

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exhaustive. Other minerals are present, *e.g.*, apatite and sillimanite, as very occasional inclusions in quartz grains; monazite and xenotime are suspected, but would require more detailed investigation to confirm.

Some of the minerals require special note. (See Fig. 1.)

Iron Pyrites.—This mineral occurs occasionally as cement, but only in small patches seldom more than half an inch across. These are more resistant than the rest of the rock and weather into prominences. Well-formed pentagonal dodecahedra were once observed.

Zircon.—The plate shows the forms in which zircon occurs. These are quite usual, and along with the typical inclusions have been frequently described. One peculiar and noteworthy point, however, is the high degree of rounding attained by the zircons. This will be dealt with later when considering the origin of the material.

Rutile.—This occurs as angular fragments, and less commonly as rounded particles. Both acicular and squat crystals are present, the former scarce, and usually golden yellow, the latter very plentiful, and with colour ranging from a rich red to a deep dark red almost opaque. Occasional geniculate twins as figured have been observed. The rutile seems to alter readily, showing every stage of alteration into apparently opaque ilmenite.

Anatase.—This is by far the most beautifully formed mineral present, and both its mode of occurrence and perfection of form indicate that most of it must have been formed *in situ*. It usually occurs growing out of spongy ilmenite, but detached crystals are common. It is usually pale green in colour, but is sometimes colourless and blotched. Single crystals seldom exceed ·1 mm. in size, but exhibit the faces perfectly. The form most frequently met with is that figured in the plate showing large basal planes (001) and small pyramids (111). Crystals showing (001), (111), and (101) are common, and combinations of (001), (111), and (110) have occasionally been observed. All the above are tabular, and none of the blue pyramidal varieties have been definitely met with.

Tourmaline.—This mineral occurs in well-rounded grains, more often in angular fragments, and occasionally in good

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crystals with rhombohedral terminations, as shown in the plate. Crystals with both ends well terminated are accounted somewhat rare among Scottish tourmalines. The predominant colour is light brown, but the colour ranges from this to almost colourless, and in all varieties the pleochroism is most intense. Inclusions are numerous, and often strangely pleochroic.

Ilmenite.—Fresh ilmenite is scarce. It occurs in rounded grains, and many of these are in a state of alteration to leucoxene, which, in incident light, is seen to form a buff-coloured incrustation.

Muscovite.—This mineral is fairly plentiful throughout the sandstone, but in some of the very fine flaggy bands it becomes the chief constituent. It is present as large irregular plates with frequent inclusions of rounded zircons.

Biotite.—This is less plentiful, but is occasionally met with, sometimes intergrown with muscovite, often perfectly fresh and strongly pleochroic, and often altered to chlorite.

Felspars.—These form less than 10 per cent. of the sandstone, and are remarkable for their freshness. The cross-hatching of microcline and the simple twinning of orthoclase are frequently seen. Albite and oligoclase have been recognised, but the majority of the plagioclase felspars are not identifiable. Many perfectly fresh cleaved grains show no twinning, have a refractive index less than that of quartz, and are probably albite.

Kaolinite.—This mineral serves as cement in the sandstone, being present as low-polarising aggregates. It is separated by washing the sand and pouring off the fine material. Good hexagonal plates are got, some perfect, but the majority lacking in parts which have been split off along the cleavages. It is a primary constituent of the sandstone, and from its occurrence in irregular patches, with sometimes an unaltered felspar fragment in the centre, it is clear that its existence is due to originally kaolinised felspars which subsequent pressure has squeezed between the sand grains so that the kaolinite now acts as cement. The presence of perfectly fresh felspar in the sandstone negatives the possibility of the kaolinisation having taken place subsequently to deposition.

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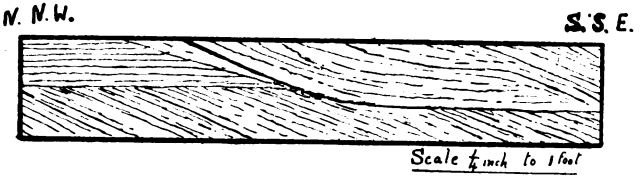
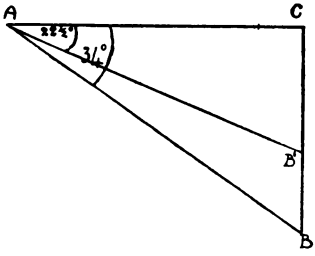
Changes in the Sandstone since Deposition.

The changes that have taken place in the sandstone have been investigated on the lines laid down by Dr. Sorby.[2] In the White Top Rock the particles average ·25 mm. diameter. The angle of repose for sand composed of such grains is 34°. The angle of drift bedding in the sandstone is now only 22½°. The diagram shows a 12-feet block of the sandstone, with well-marked drift bedding as distinguished from the oft-figured current or false bedding. The lower half of the block shows





B C represents original volume of deposit—100 per cent.

B′C represents present volume—61 per cent.

B B′ represents the contraction—39 per cent.

Angle C A B = 34° = Angle of repose of sand.

Angle C A B′ = 22½° = Angle of drift bedding.

it most regularly, giving exactly the appearance one would expect in a section through a tip-heap. These angles are all very near to 22½°. Here the current has been from the N.N.W., and a section at right angles to this shows typical false bedding. Drawing the angles as shown indicates fairly accurately the contraction, which in this case has been 39 per cent.

[2] *Q. J. G. S.*, 1908. H. C. Sorby. "On the application of Quantitative Methods to the Study of the Structure and History of Rocks."

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This shrinkage is due in part to removal of material by solution and to the filling of interspaces by kaolinised felspars. Now, the sand derived by disintegrating the sandstone is found to possess 47·08 per cent. of interspaces. By reducing 100 volumes of this sand to 61 volumes, and supposing none of the solid material removed, there would remain 8·08 volumes of interspaces and the original 52·92 volumes of solid material. These interspaces would now represent 13·25 per cent. of the whole. In the present sandstone the average of a number of determinations of interspaces is 20·35 per cent. Collecting these results:—

Interspaces in derived sand, - - -	47·08 per cent.
Ideal Interspaces on shrinking, 39 per cent.,	13·25 ,,
Actual Interspaces in present sandstone, -	20·35 ,,

This indicates that an appreciable amount of material must have been removed in solution, not only to account for the difference between 20·35 per cent. and 13·25 per cent., but also to counterbalance anything which may have been added by solutions. Much of the removal by solution may have been nothing more than migration of the material to another part of the sandstone, for the White Top Rock contains much "whin" in which the interspaces are only 5 per cent. of the bulk.

The above evidence, coupled with the fact that the sandstone now contains practically nothing but the most stable minerals, points to the conclusion that very little material could have been added to the deposit by subsequent infiltration. The only doubtful mineral in this respect is the universally present hæmatite, the irregularly distributed and scanty calcite being neglected. This ferric oxide could not have been deposited *pari passu* with the accumulation of the sand, for, as will be shown later, deposition was not in a region of inland drainage, neither was decaying vegetable matter absent.[3] The sandstone at present does not contain ferro-magnesian minerals in any appreciable quantity, and magnetite is absent. Thus, it is possible that the 2 or 3 per cent. of hæmatite at present colouring the sandstone may have been derived mainly from

[3] *Trans., Edin. G.S.*, vol. 7. J. G. Goodchild. "Desert Conditions in Britain."

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minerals initially present. The way in which the ilmenite is altering into anatase and necessarily setting free the iron may be typical of the whole process.

The Source of the Material.

The only reliable evidence available for determination of the source of the material is that got from a study of the individual particles. All other means have proved futile in this case. Taking percentages of the heavy minerals, as has already been shown, was quite unsatisfactory. Increasing or diminishing size of particle is likewise valueless owing to like reasons, viz., uncertainty of horizon and irregular and rapid change in the sediment. Bedding and channel cutting are of some value, but interference by local currents is apt to obscure the evidence for the main current. Being thus forced to rely on the grains of the constituent minerals it is fortunate that their evidence is unequivocal. The state of wear of the grains, the inclusions, and the minerals present, all bear witness to the one origin. The shapes of the grains vary from perfect millet seed types to quite unworn angular fragments. Even some of the largest grains, which would round rapidly with travel, are got showing sharp angles and a glassy fresh appearance, as if coming from no great distance, so that such grains might be taken as representing the contribution of the nearest part of the parent mass, and thus roughly fix its position. The inclusions contained in the grains have been studied after the method advised by Dr. Mackie.[4] He states the following general law:—"Acicular and irregular inclusions abound in the quartz of granite. Regular inclusions are to be found in various proportions, but always in relatively large numbers in the quartz of gneiss and schist." The regular inclusions in this case are the same minerals as occur in the heavy residues, *i.e.*, mainly zircon, tourmaline, rutile, and ilmenite. These, occurring more often as rounded grains than well-formed crystals, are found to be present in between 40 and 50 per cent. of the quartz grains, while typical acicular inclusions are found in no more than 6 per cent. of the grains. The quartz grain shown in the plate (Fig.

[4] *Trans., Edin. G. S.*, vol. 7. W. Mackie. "The Sands and Sandstones of Eastern Moray."

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1, D) is an excellent example of a grain containing regular inclusions. In this grain the inclusions are exceptionolly large and numerous, but otherwise it is quite typical. The high percentage of such grains clearly indicates that the bulk of the material was derived from an area of crystalline schists and gneisses. Unfortunately the sandstone does not contain a single rock fragment, unless a compound quartz grain can be considered a fragment of quartzite, or an intergrowth of muscovite and biotite a fragment of mica-schist. The absence of fragments of recognisable rocks prevents the correlation with well-known rocks, and renders exact localising of the parent mass somewhat speculative. Further, when the vast amount of denudation since Carboniferous times is considered, it would be unwise to suppose that exact counterparts of the rocks now exposed were then being denuded. While enumerating the difficulties here it might be well to voice again the universal wail of all workers in sedimentary rocks, viz., insufficient knowledge of the rocks which probably contributed the material. "To trace the parent rocks we must be armed with microscopic sections of all rocks in the neighbourhood."

Having bedding showing currents from directions more or less N.W., and having evidence pointing to an area of crystalline schists as the parent mass, and that at no great distance either, a glance at the map shows that the W. or N.W. is the direction of the source. The Highlands probably remained above water throughout Carboniferous times, for even the Carboniferous Limestone Series is not wholly marine, and from this land extending to some distance south of the boundary fault, the material must have come. Still bearing in mind the difficulties and uncertainty of exact localising, it is nevertheless interesting to see what degree of correspondence exists between the minerals of the sandstone and those in any special area. It is found that the Cowal district answers excellently in this respect. Eliminate the authigenous minerals of the sandstone, and eliminate the unstable minerals in the Cowal schists, and practically the same list of minerals is got. Many of the minerals, of course, are such as would be got in any sandstone, and might be furnished by any metamorphic area; but, considering a mineral such as tourmaline, which can be got in an infinite variety of shades, it is found that the

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few varieties got in the sandstone can be exactly matched in Cowal. Again, apatite is seldom met with in the Cowal district, and in the sandstone it has not been observed except for an occasional doubtful inclusion. Mineral for mineral this correspondence continues till a quite inexplicable anomaly appears. Cowal is teeming with garnets, yet careful search of numerous heavy residues has not revealed a single scrap of garnet in the sandstone. Explanations of this might be attempted in three ways—(1) It might be merely postulated that, in late Carboniferous times, the rocks undergoing denudation were barren of garnets. This does not seem likely in the face of a suite of minerals pointing to rocks similar in essentials to those at present exposed. (2) We might suppose the distribution of garnets in Cowal the same in Carboniferous times as at present. Going on this assumption it would be possible for a river coming from the west to avoid the region rich in garnets, since south of Newton, on Loch Fyne, garnets are very scarce. The most that can be said for this theory is that it is a possibility, but it is unlikely that the garnet rich area would not be tapped by some tributary, even if it were missed by the main stream. (3) The third theory would explain the difficulty by putting garnet among the minerals not stable enough to persist in the sandstone. Several facts render this unlikely—(*a*) The garnets in the schists weather out as hard parts. (*b*) They can withstand the wear of travel, for they abound in the sand brought down by the streams flowing through the area. (*c*) They are plentiful in other sandstones.[5] (*d*) When a mineral, such as biotite, is got still fresh in the sandstone there is no reason for supposing special circumstances or agents of weathering to have attacked this sandstone. In short, there seems to be no good reason why garnets should not be present.[6]

Before leaving the question of the rocks which supplied the material, reference must be made to the peculiar condition of the zircons in the sandstone and the light they throw on the

[5] *Q. J. G. S.*, 1909. H. H. Thomas. "A Contribution to the Petrography of the New Red Sandstone in the West of England."

[6] Since the reading of this paper, a continuation of the work among the thin sandstones in the lower half of the Red Measures has revealed the presence of garnets in addition to the other minerals. This makes the case for explanation (2) much stronger.

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problem. Zircon is by far the most plentiful of the heavy minerals, and the grains are rounded in a most striking fashion, so much so that, for comparison, an analysis of the grains of zircon, tourmaline, and rutile was made, since these three compose the bulk of the heavy residues. Three degrees were used—a = angular; r = rounded, and R = perfectly rounded, wind polished. From an examination of several hundreds of grains taken from all localities the following percentage results were got:—

	a	r	R
Tourmaline, - -	67	28	5
Rutile, - - -	73	23	4
Zircon, - - -	19	37	44

The tourmaline and rutile show practically the same amount of rounding as the rest of the minerals present in the sandstone, and the degree of rounding is normal for water carriage, but the zircons show no less than 44 per cent. of beautifully rounded grains, with surfaces like ground glass. Many of these grains are less than ·1 mm. in diameter, and this is the limit at which Daubrée says the power of water to round grains ceases. Wind action, on the other hand, can round almost any size of particle. The natural inference is that these are wind-blown particles. Now, older palæozoic rocks, especially the Old Red Sandstone, must have contributed material to this deposit, but we cannot attribute the rounded zircons to such, for there would be a like proportion of rounded grains among the other constituent minerals. Neither can the state of the zircons be explained by the fact that zircon is more readily rounded than quartz, for in the table of relative "psephicities" or "coefficients of roundability" given by Dr. Mackie,[7] the following order holds:—Quartz, ·23; tourmaline, ·3; zircon, ·45; rutile, ·51. These values are calculated for the rounding of a cube of each mineral, so that commencing with a squat crystal of tourmaline it would be rounded much faster than its place in the table would indicate. [See plate, Fig. 1, B, Tourmaline.] This would account for the tourmalines being slightly better rounded than the rutiles. No explanation of this kind can account for the very high degree of rounding attained by the zircons. While

[7] *Trans., Edin. G. S.*, vol. 7. W. Mackie. "On the Laws that Govern the Rounding of Particles."

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admitting the possibility of chemical change being responsible, considering the susceptibility of zircon to pneumatolytic action, still the most probable and straightforward explanation is that the grains are wind worn, and they might be accounted for in the following way:—Zircon is one of the most stable minerals, remaining unaltered even when rocks have been recrystallised. Many of the zircons in the sandstone have been derived from crystalline rocks, say, quartzites, which have originally been laid down as wind deposits. Recrystallisation would obliterate the forms of the other grains, but leave the stable zircons unaltered. This is the only explanation the evidence permits, even in the teeth of the fact that there is no evidence of wind action in Dalradian times. If we grant this history of the zircons, and consider that the Clyde is at present cutting down the sandstone and carrying off these same zircon grains once again, it brings home the full meaning of Dr. Sorby's dictum—"In the first place, it is important to distinguish between the age of the grains and the age of the deposit. A very ancient sand may be made up of grains practically new and unworn, whilst, on the contrary, the grains of a modern sea beach may be of vast antiquity, may have passed through the greatest vicissitudes, may have successively formed a part of several different geological formations, and may be greatly altered and worn."[8]

Conditions under which Deposition Occurred.

In the majority of cases the most reliable evidence bearing on the conditions of deposition is got from the fossils present. In the Upper Red Barren Measures the absence of such evidence makes it necessary to depend on less reliable criteria. Even the very fact that signs of former life are almost wholly wanting does not make it certain that the conditions were unfavourable to life, but rather that the deposit has proved unsuitable for preserving evidence. The coarse and porous nature of the sandstone and the working of solutions through it would afford little chance of preservation to delicate organisms entombed in it. This fact being recognised, the fine-grained

[8] *Q. J. G. S.*, 1880. H. C. Sorby. "Anniversary Address of the President."

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purple shale in Bell's Quarry was searched, and fairly numerous plant remains were discovered. They were in a very poor state of preservation, and Dr. Kidston, who very kindly examined them, pronounced them unidentifiable, with the exception of one or two which may have been fragments of *Calamites*. Although these uncertain fossils give no aid in fixing the exact stratigraphical position of these Red Measures, they at least show that life was neither absent nor scarce; besides, they indicate possibilities in this old exposure in Bell's Quarry. It may have been here that the silent workers of 1840 got the data which enabled them to remove these sandstones from the Old Red Sandstone to the Carboniferous.

Climatic Conditions.—Dr. Mackie[9] has shown how the felspars present in sedimentary rocks can indicate the climate prevailing at the time of deposition, and although, in many cases, the method becomes unreliable, in this case complications are fortunately scarce, and the evidence is correspondingly more convincing. Stated as briefly as possible the principle is that fresh felspars indicate the operation of mechanical agents of weathering, thus pointing to a cold or a very warm and dry climate, while kaolinised felspars indicate chemical agencies, and therefore a temperate and humid climate. In the sandstone under consideration practically all the felspars would be classed as fresh, while the kaolinite cement must represent what would originally be kaolinised felspar grains. Complications arise when the felspars in the sediment represent a concentrate composed only of the more stable potash felspars, but this gives no trouble in the present case, because (1) although microcline is most abundant, it occurs universally in the metamorphic parent rocks often to the exclusion of other felspars; and (2) although plagioclase felspars are less plentiful they do occur, and are perfectly fresh, showing good twinning and polarisation colours. Lastly, they are often sharply angular, the sure sign of original freshness, so that kaolinisation of felspar fragments subsequently to deposition may be neglected. Thus, roughly speaking, it may be said that in the original sand the felspar grains were laid down in two con-

[9] *Trans., Edin. G. S.*, vol. 7. W. Mackie. "On the Felspars present in Sedimentary Rocks as Indicators of the Conditions of Contemporaneous Climate."

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ditions, the majority as perfectly fresh fragments, and the rest as soft kaolinised grains. Keeping in view the possibility of the evidence being to some extent falsified by many of these grains being derived from earlier palæozoic sediments, it still seems possible to submit the country to the same rough division to correspond with the felspars. A fringe of land enjoying a humid climate would account at once for the plant remains and the kaolinised felspars, while the abundant fresh felspars could be explained by a more elevated hinterland stretching far inland and enjoying a warm climate more free from moisture.

The Productive Coal Measures, and even the lower half of the Upper Red Barren Measures, with their thin coals and fire-clays, indicate terrestrial and lagoon conditions, but the massive sandstones in the upper half have the appearance of a deposit laid down in the tidal flats of an expansive estuary. The Liver Rock below, with its regular bedding, indicates deeper water with a strong current above raining in the larger particles among the material brought by the slower bottom current, while the White Top Rock exhibits all the phenomena of a shallower water deposit within the influence of the tide. Local variations of current, channel cutting, pockets of mica, and fine silt settled in the flat, shallow pools isolated by the re-treating tide, badly preserved rain-marks—all signs indicate the sand flats of an estuary with differential subsidence keeping pace with the rate of deposition. The absence of indications of the life which must have existed both here and on the land hard by has already been explained.

Investigation[10] of palæozoic sediments in general has shown that a vast quantity of pre-Cambrian material has gone to form them. This is explained by the proximity of the ancient continent of Arctis which linked the Scottish Highlands with the Scandinavian Peninsula, and stretched far to the N.W. with a gentle slope to the S.E. The material composing the sand-stones of the Upper Red Barren Measures must have been transported from this continent by an immense river coming from the W. or N.W., and, at the embouchure of this long, low

[10] B. A. Report, 1886, p. 601. Prof. T. G. Bonney. "The Application of Microscope Analysis to discovering the Physical Geography of Bye-gone Ages."

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river, the travel-worn grains from the country beyond were deposited, covered, and finally re-exposed as the Red Sandstone now occupying the centre of the Glasgow basin.

In conclusion, it only remains for me to thank the many friends who have assisted me in this work. I am indebted to Mr. Fleck for his help with the camera and his company in the field; to Mr. Scott for chemical analyses; and to Mr. Skilling's truthful pen for the plate of the heavy minerals. For affording me every facility for study I am indebted to Mr. King, managing director of the Bothwell Park Quarries. Lastly, to Professor Gregory and Mr. Tyrrell I owe most, having received not only the encouragement and moral support necessary in a first work of this kind, but also frequent practical assistance.

EXPLANATION OF PLATES.

FIG. 1—A. Rutile, (1) geniculate twin × about 50.
,, (2) acicular crystal × about 50.
,, (3) typical angular fragment × about 50.
B. Tourmaline, (1) crystal with perfect rhombohedral termination × about 50.
(2) and (3) different stages of rounding × about 50.
C. Anatase, (1) small crystals growing out of spongy ilmenite × about 20.
,, (2) commonest form showing (001) and (111) × about 200.
,, (3) crystal showing (001), (111) and (101) × about 200.
D. Zircon, (1)—(5) crystals showing stages in rounding × about 50.
,, (6) quartz grain specially rich in typical inclusions which are rounded zircons, tourmalines and ilmenites × about 50.

FIG. 2—"Whin" from whinnybole in White Top Rock, Fallside × 24.

FIG. 3—White Top Rock, Fallside × 24.

FIG. 4—Spherulitic jointing in Sandstone, Bothwell Park Quarries, Fallside.

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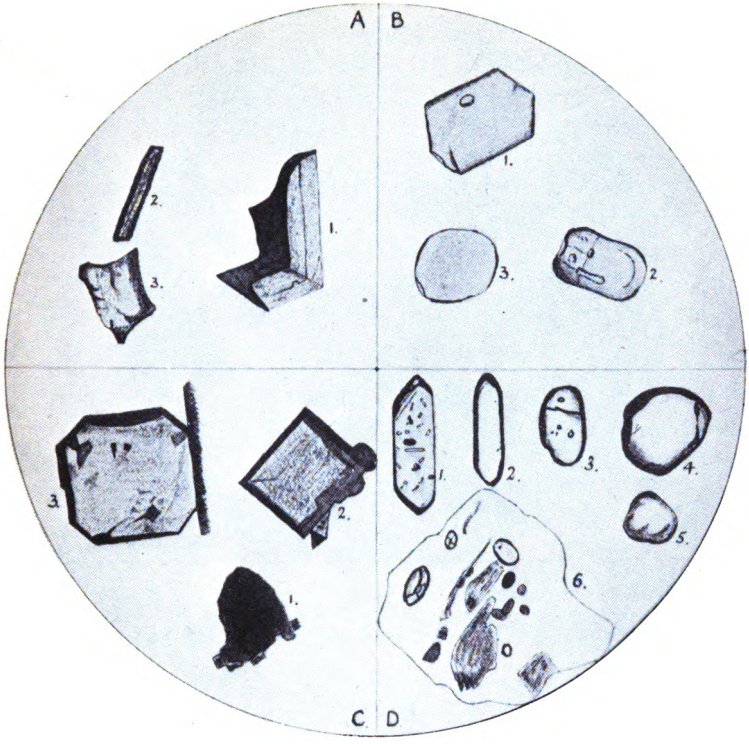

Fig. 1.
Photo-micrograph of Heavy Minerals from the Sandstone.

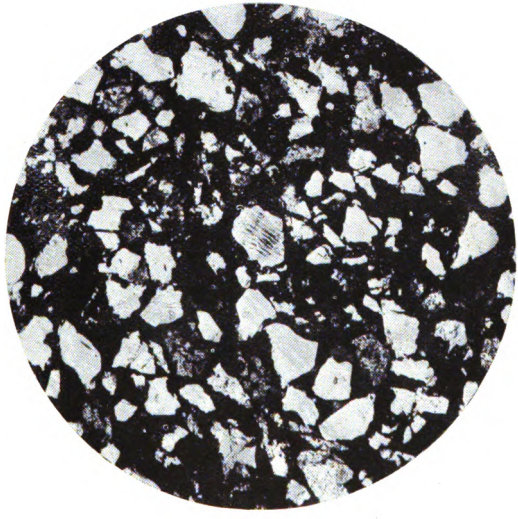

Fig. 2.
Photo-micrograph of thin section of "Whin."

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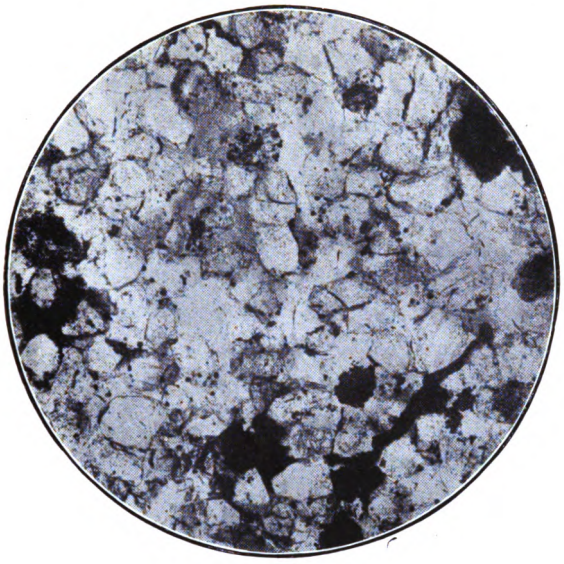

Fig. 3.

Photo-micrograph of thin section of Sandstone (White Top Rock), Fallside.

Fig. 4.

Spherulitic Jointing in Sandstone, Bothwell Park Quarries, Fallside.

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No. XI.—The Garriongill Section at Overtown, near Wishaw.[1] By M. Macgregor, B.Sc.

[Read 14th March, 1912.]

The object of this paper is to describe in detail a natural section in the Upper Carboniferous of the West of Scotland that has been somewhat neglected by Glasgow geologists. The Garrion Burn lies, roughly, 1½ miles S.W. of Wishaw, and is easily accessible from Glasgow by train to Overtown or to Law Junction. It was mapped on the 6-inch scale by the Geological Survey of Scotland in 1869-70 (see published 6-inch sheets of H.M. Geological Survey of Scotland, Lanark, 18 N.E. and S.E.), but no account of the section has so far been published.

The Garrion rises near Bentyhillocks on the S.W. edge of Auchterhead Muir, and enters the Clyde opposite Dalserf. For the first few miles it pursues a winding course among boulder-clay drumlins, and only at one point exposes a section worthy of particular remark. This is at Hyndman Bridge, where a little rock is seen the stratigraphical position of which lies about the base of the Coal Measures. It is not, however, until the burn reaches the sharp S.W. bend just N. of Gillhead Farm that it leaves the boulder clay and enters on the long rock section described below. From this point to Garriongill Bridge, near the Clyde, there is a fairly complete section of the strata lying between the Kiltongue Coal and a horizon approximately 50 to 53 fathoms above the Ell Coal of Lanarkshire.

1. *Kiltongue Coal.*—This is exposed on the left bank of the burn slightly west of south of Garrion Burn Cottage. The full thickness is not seen, but the coal was worked at the crop here during the recent strike, and over 2 feet 8 inches exposed. From bores in the immediate neighbourhood the average thickness in the ground to the north is 2 feet 11½ inches, and in the ground lying south of the burn 3 feet 6 inches. The Kiltongue

[1] Communicated by permission of the Director of H.M. Geological Survey.

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Coal here is a clean uniform seam of bright coal, producing a house fuel of excellent quality.

2. *Strata between Kiltongue Musselband and Kiltongue Coal.*—These strata are seen in small exposures just east of Gillhead Bridge[2] and (less completely) west of Garrion Burn Cottage. The section is as follows:—

	Feet.	Inches.
Fireclay, blaes, and ironstone balls,	3	6
Sandstone and fakes,	10	0
Blaes,	2	10½
Ironstone rib (persistent) up to,	0	1¾
Blaes and ironstone ribs,	2	3
Fakes (not well seen), about	4	6
Blaes and ironstone ribs,	2	7
Probable gap,	3	0
Fakes,	2	6
Sandstone,	1	0
Fakey blaes, with irregular sandstone ribs,	5	1
Dark blaes,	0	3
Kiltongue Coal—base not seen.		

The total thickness is 6 fathoms 1 foot 8¼ inches, but the section is pieced together from four different exposures, and cannot be quite satisfactory. The average thickness in eight neighbouring bores is 6½ fathoms, and the strata met with are mainly sandstone and fakes, with a few feet of blaes, often containing a thin coal seam in the middle; this agrees fairly well with the section given above.

3. *Kiltongue Musselband.*—This horizon forms a valuable index throughout Lanarkshire. At four different points in the Garrion excellent sections are exposed. The most easterly of these lies 117 yards east of Gillhead Bridge, and shows the following:—

	Feet.	Inches.
Tough shale (cannel),	?	
Musselband,	0	9½
Ironstone,	0	1¼
Dark fireclay,	?	

[2] This and other place names mentioned are taken from Ordnance Survey 6-inch sheets.

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The beds here have a slight dip up stream, and the ironstone can be followed from the point where it crosses the burn for 30 yards westward along the left bank. It is again finely exposed in several sections, near old Garriongill Mill.[3]

Section A, on railway embankment above burn, 60 yards or so east of the mill—

	Feet.	Inches.
Sandstone,	6	0+
Dark blaes,	1	5
Tough cannel-shale, with fish teeth,	0	5½
Musselband,	0	9
Ironstone, 0 ft. 1 in. to	0	2

Section B, at old eye on right bank, at mill—

	Feet.	Inches.
Thick sandstone,	?	
Dark blaes (with plants),	1	5½
(Local) Ironstone, full of "mussel" shells, 0 ins. to	0	1½
Shale, Entoms at top,	0	3½
Tough shale, with fish-scales, teeth, and *Calamite* impressions,	0	4
Musselband,	0	8¼
Ironstone, up to	0	2½
Soft blaes,	?	

Section C, at ford, west of mill, left bank—a magnificent exposure—

	Feet.	Inches.
Thick sandstone,	?	
Dark shaly blaes,	1	4½
Tough cannel or oil-shale,	0	4
Black shale,	0	2½
Musselband,	0	5½
Ironstone, ½ in. to	0	2¾
Musselband (local),	0	1
Soft fireclay blaes,	1	0

This horizon, being very constant over a wide area, forms a valuable index in mining; it separates the Kiltongue Coal and the Drumgray seams from the Virtuewell and thick upper coals of Lanarkshire.

[3] Now a ruin; it lies at the bend just east of "stepping-stones."

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The oil shale is a very tough, dull-looking rock, difficult to kindle, but burning with a bright flame. It resembles in appearance the well-known cannel coal of Torbanehill. The underlying musselband is a reddish-weathering band of shale crowded with shells of *Carbonicola*.

4. *Ladygrange Coal to Kiltongue Musselband.*—This part of the section is seen just east of the Caledonian Railway Pumping Station—

	Feet.	Inches.
Ladygrange Coal (parrot),	(0	7½)
Coaly fireclay,	0	3
Fireclay,	0	5
Blaes,	5	6
Fakes and sandstone,	7	1
Blaes and ironstone ribs,	8	6
Fakes and blaes,	8	6
Dark blaes,	1	1
Sandstone,	about 33	0
	10 fms. 4	4½

5. *Ladygrange Coal.*—The probable representative of the Ladygrange seam shows the following section:—

	Feet.	Inches.
Oil shale with "mussels,"		
Entomostraca, fish-teeth, and plant remains,	0	4
Blaes,	0	2
Fireclay and blaes,	0	9
Coal (parrot),	0	7½
Coaly fireclay,	0	3
Fireclay,	0	5

The seam is local and variable throughout Lanarkshire. In the Garrion Burn area it varies from 4 inches to 7½ inches, and its distance above the K. Musselband may be 8⅓ to 11½ fathoms. The same seam at Shotts and Fauldhouse reaches 1 foot 7 inches, and lies 9½ to 11½ fathoms above the Musselband. In the Arden Basin[4] it is 2 feet, and lies 8 fathoms above the Musselband. Westwards it seems to be very poor or absent; it occurs in the Rutherglen and Shettleston fields, but elsewhere near Glasgow is wanting. It is commonly underlain by a thin rib of ironstone.

[4] See Geological Survey Memoir on sheet 31, page 36.

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6. *Virtuewell Coal to Ladygrange Coal.*—This section is a direct continuation of the last—

	Feet.	Inches.
Virtuewell Coal,	(3	11½)
Fireclay,	0	2
Sandstone and fakes, some blaes,	21	8½
Blaes,	2	6
Shaly blaes and ironstone ribs with "mussels" and Entomostraca,	0	8[5]
Fireclay blaes,	3	6
Sandstone,	16	9
Blaes, with ironstone balls and ribs,	3	0
Coaly blaes,	0	1
Oil shale, with *Carbonicola*, Entoms., &c.,	0	4
Fireclay and blaes,	0	11
	8 fms.	1 7½

7. *Virtuewell Coal.*—This seam is exposed on the left bank of burn just above mouth of tunnel at pumping station, and shows the following section:—

	Feet.	Inches.
Shale, with fish teeth, &c.,	0	3
Hard coal,	2	1
Softer coal,	0	9
Hard coal,	1	1½

This coal is one of the most valuable seams in the Lanarkshire field. It varies somewhat in thickness throughout the Wishaw-Law area; at Harestonhills it is 2 feet 9 inches, and has a 5-inch parrot coal on top; at Lanniesmuir it is 3 feet 1 inch, with an overlying 2 inches of parrot; at Garriongill Colliery it is 2 feet 9 inches, and on Wemysshill Farm it is only 1 foot 1 inch. Its distance above the Ladygrange varies between 8 and 9½ fathoms.

At Shotts and Fauldhouse, where it goes under the name of Benhar Coal, it is 3 feet 6 inches and 4 feet respectively.

8. *Splint Coal to Virtuewell Coal.*—This part of the section is unfortunately obscured by the Caledonian Railway embankment. The following are the actual exposures seen in the burn:—

	Feet.	Inches.
Gap with old day level to Splint Coal,	?	
Sandstone,	15	3
Coaly shale with "mussels,"	0	7½

[5] An ironstone in approximately this position was worked in the Greenhill and Cleland district, under the name of the Bellside Ironstone. See Geological Survey Memoir on sheet 31, page 34.

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		Feet.	Inches.
	Blaes with ribs and balls of ironstone,	12 to 14	3
	Sandstone,	2	0
	Blaes and sandstone ribs,	8	10
	Dirty coal,	0	3
	Coal,	0	3
	Blaes and balls,	4	8
	Kingly sandstone,	3	8½
	Blaes and ironstone ribs,	4	2½
	Coal,	0	3½
	Sandstone,	0	10
	Blaes and balls,	5	0
	Broken rock of fault,	?	
	Coal with slaty rib,	1	4
	Fireclay,	0	7
	Blaes and balls with ribs of kingle,	7	0½
	Gap, due to railway embankments,	?	
	Sandstone and fakes,	10	4
	Thin coal (not now visible),	?	
	Gap, probably with fault,	?	
See above	Shale, Virtuewell Coal,	0	3

It is unfortunate that there are no bores from the Splint to the Virtuewell seams at any point close to the section. From bores in the surrounding country the following data are available :—

The Virtuewell Coal is succeeded directly, or after a few feet of fakes, by a bed of blaes containing ribs of ironstone. The name given to this horizon is the Roughband Ironstone.[6] It is not exposed in the Garrion.

The next horizon of importance is a seam of coal lying between 9 and 11 fathoms above the Virtuewell. It is described as slaty, and may occur in two leaves, and is generally succeeded by several fathoms of fakes and sandstone. It is possibly represented by the 1 foot 4 inches coal of the above section. This seam appears to occupy the position of the Airdrie Blackband Ironstone, or the Blackband Coal which over most of the Lanarkshire field represents that horizon. Where of workable thickness, as at Viewpark, near Uddingston, and at Starryshaw, near Fauldhouse, it furnishes an excellent house coal. Generally it is poorly developed.

About 6 fathoms above the Blackband position occurs a

[6] The Roughband of Newarthill and Cleland lies also from 9 inches to 2 fathoms above the Virtuewell.

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9 inches to 1 foot 3 inches coal, succeeded generally by a great thickness of blaes and ironstone ribs, and a thick post of sandstone. It lies 10 fathoms below the Splint. This may possibly be represented in the Garrion by the higher of the two thin seams of the above section. Either this or the dark mussel shale, 3½ fathoms above, may represent the Musselband Coal of Rutherglen, &c. This, however, is a variable and impersistent seam, and cannot be identified with certainty in the Garrion area.

9. *Splint Coal.*—This seam is not now seen in natural section, but its position is fixed by old day levels. On Gillhead and Lawmuir its thickness was 6 feet. It is a hard, splinty seam, with ribs of dull cannel or parrot coal; the roof is a bed of blaes with ironstone balls, and the floor a thin fireclay. The Virgin Coal is not here a distinct seam.

10. *Main Coal to Splint Coal.*—This portion of the section is best seen between the day level to the Splint Coal, and the little bridge that crosses the Garrion about 500 yards S.W. of the pumping station.

Main Coal (see second section under Main Coal)—

		Feet.	Inches.
Left bank of burn.	Blaes and Ironstone balls,	4	6
	Fakes and sandstone,	8	2
	Blaes,	1	9
	Coal,	0	5
	Fireclay,	0	2½
	Fakes and sandstone,	20	10
	Blaes and ironstone ribs,	1	3
	Shale with *Carbonicola*,	0	11
	Blaes and ironstone ribs,	1	10½
Right bank of burn.	Dark blaes,	0	10
	Blaes and balls of ironstone,	8	6
	Ironstone,	up to 0	6
	Blaes and ironstone ribs,	1	2
	Coal,	0	2
	Blaes and balls of ironstone,	8	2½
	Sandstone and fakes,	9	4
	Blaes,	3	0
	Sandstone,	5	2
	Blaes,	1	0
	Sandstone,	5	0
	Blaes with plants,	3 or 4	0
	Eye to Splint Coal,	-	
		14 fms. 2	9½

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The average distance between the Splint and Main Coals in this area is 14½ fathoms. The position of the Humph Coal of Cambuslang and Uddingston, which lies about 5 fathoms above the Splint, is probably represented by the 2 inches coaly layer of above section. Good sections of the same strata are seen on both sides of the burn, below the first crop of the Main Coal.

11. *Main Coal.*—This valuable and well-known seam can be seen at four points, viz.:—

1. Side of railway at Garriongill Junction.
2. Left bank of burn above little bridge, a continuation of Splint to Main section given above.
3. Left bank, S. of Garriongill Junction.
4. Day level, S. of little bridge.

The following are the sections:—

1.	Ft.	Ins.
Blaes,	0	6
Hard coal,	2	8
Dirty coal,	0	5½
Hard coal,	2	0
Fireclay,	0	2
Thickness of coal,	5	1½

2.	Ft.	Ins.
Blaes,	0	7½
Hard coal,	2	6½
Soft coal,	0	5
Hard coal,	2	0+
Fireclay,	?	
	4	11½+

3.	Ft.	Ins.
Blaes,	?	
Dirty coal,	0	3
Coal,	1	8
Coaly shale,	0	1
Thickness of coal,	1	11+

4.	Ft.	Ins.
Blaes,	0	6½
Coal,	2	9
Dirty band,	0	5
Coal,	2	0
Fireclay,	?	
	5	2

Section 3 shows a local "wash-out" of the higher part of seam.

The thickness at Castlehill Pit was 4 feet 7 inches; at Shawfield Pit, 4 feet 11 inches; at Garriongill and Law Collieries, 4 feet 9 inches; there is a thin parting of soft, dirty coal towards the middle of the seam.

12. *Ell Coal to Main Coal.*—These strata are partially exposed in several sections. Of these, the best are—

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Main Coal upwards

1. Right bank between little bridge and crop of Ell Coal.
2. Left bank do. do. do. do.

Pyotshaw position to Ell.

3. Left bank above bridge at Castlehill orchard (S. of big fault).
4. Left bank just S.W. of 20 fathom fault at Castlehill Pit.

	Feet.	Inches.
(Floor of Ell Coal) not seen,	?	

At first bend south of little bridge.

	Feet.	Inches.
Fakes and blaes,	3	10
Fakes and sandstone,	4	1
Gap,	? 3	0
Sandstone and fakes,	4	0
Gap (some blaes and fakes seen),	? 6	0
Blaes and ironstone ribs,	10	7
Ironstone,	0	6
Blaes and ironstone ribs,	3	0½

Right bank just S. of little bridge at side of footpath.

	Feet.	Inches.
Fakes and sandstone,	5	7
Blaes and ironstone ribs,	1	9½
Dark shaly blaes with a few "mussels," *Neuropteris*, &c.,	0	7[7]
Blaes and ironstone ribs,	0	10
Coaly layer,	0	1½
Blaes and ironstone ribs,	5	3
Fakes,	2	1
Blaes and ironstone ribs,	0	4½
Shale,	0	5½
Coal,	0	11
Dirty coal,	0	3
Blaes and ironstone balls,	3	0
Fakes and sandstone,	2	9
Reddened fakes,	about 3	6
Burnt shale,	0	6
White trap,	0	1½
Dirty soft coal,	0	3
Hard coal (burnt),	6½ to 0	7½
Soft coal,	2 to 0	2½

Continuation of Splint to Main section above; left bank just above little bridge.

Fakey blaes with ironstone balls,	about 6	0
Sandy fakes,	5	1
Thin bedded fakes with harder ribs,	4	0
Blaes,	0	6
Coal,	0	⅓
Fireclay blaes,	0	7½
(Main Coal),		

[7] This band is known at Rutherglen and Cambuslang.

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The distance between the Ell and Main Coals varies in this area from 10 to 15 fathoms, so that the above section is a fair average.

It may be remarked here that the metals above the Main Coal position tend to vary somewhat from point to point. The Pyotshaw seam, for example, is irregular in thickness and in distance above the Main; it is thick enough to be worked by coal-cutting machines in Straven Colliery, about ¾ of a mile east of the Garrion, and the floor at times comes dangerously near the old workings of the Main. A bore near Castlehill Pit gives its distance above the Main as 5 fathoms and its thickness as 1 foot 1½ inches. In the Garrion Burn the 13-inch coal of the above section probably represents it. The 11-inch coal is well seen also at localities 3 and 4. The former of these shows a rich plant bed lying 2⅓ fathoms above the coal. The following plants from this bed have been determined by Dr. Kidston:—

Sphenopteris furcata.
Sphenopteris latifolia.
Mariopteris muricata.
Annularia radiata.
Neuropteris gigantea.
Neuropteris heterophylla.
Calamites undulatus.
Asterophyllites equisetiformis.
Sphenophyllum cuneifolium.
Lepidophloios acerosus.
Cordaites principalis.

Some of the members of this assemblage indicate Middle Coal Measure affinities; *Neuropteris heterophylla*, on the other hand, is regarded by Dr. Kidston as characteristic of the Lower Coal Measure or Lanarkian Series.[8]

This part of the section is marked by the occurrence of thin sills of "white trap." These sills or "floats" occur at different levels in the Law and Shawfield coalfield. In the Brownlie workings the Kiltongue is locally overlain by an 8 to 12-inch sill, and in the Straven Colliery the roof of the Pyotshaw is also of "whin." A thin "white trap" occurs above the coal (probably the Pyotshaw) seen at the mouth of the

[8] See Kidston—*Proceedings Roy. Phy. Soc.*, Edin., 1893, vol. xii., p. 225.

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first Main Coal day level on the right bank of the Garrion; another is seen in locality 3, 6⅓ fathoms above the Pyotshaw position; and another in locality 4, on a slightly lower horizon.

13. *Ell Coal.*—This coal is partially exposed on the left bank of the burn at bend just above the Gill Pit of Shawfield Colliery—

	Feet.	Inches.
Coal,	2	6 +
Fireclay and blaes,	1	10
Fakes,	8	0

It outcrops also on the side of railway about 300 yards west of Garriongill Junction, but the crop is now obscured.

The section at Castlehill Pit was—

	Feet.	Inches.
Blaes,	1 ft. 6 in. to 4	0
Coal,	9	3⅜
Fireclay,	2	1

14. *Upper Coal (?) to Ell Coal.*—These strata are seen—

1. Immediately N. and S. of bridge at Castlehill Orchard.
2. At sharp bend 500 yards up stream from Castlehill Bridge.

Section 1 is as follows:—

		Feet	Inches.
Left bank below bridge.	Coal,	1	5½
	Dirty coal,	0	3
	Hard coal,	1	1½
	Dirty coal,	0	2
	Hard coal,	0	5½
	Fireclay,	0	9
	Sandstone and fakes,	23	9½
	Blaes,	1	2
	Pyritous coal, Fireclay, Pyritous coal (1 ft. 11½ ins.)	1	1
		0	7
		0	3½ [9]
Right bank below bridge.	Coaly clay,	0	5
	Fireclay,	0	4
	Gap, 1 fathom	5	0
	Blaes and fakes (badly seen), say 4 fathoms	3	11
Left bank above bridge—Sandstone and fakes 12 ,,		0	11

[9] In section 2 this coal is 2 ft. 4 in., including a 4½ in. fireclay.

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The total thickness is about 24 fathoms; a rough estimate of section 2 gives the same metals as 25 fathoms, but neither section is complete, and the measurements are only approximate. A good average for the district is 26 fathoms. Further west the distance decreases; at Pather Farm it is 17⅔ fathoms; near Motherwell about 16 fathoms; and at Rutherglen only 13 fathoms. To the south it decreases also.

15. *Top of Section to Upper Coal—*

		Feet.	Inches.
Right bank between 65 fathom fault and Upper ? Coal.	Sandstone and fakes, approx.,	30	0
	Gap, very approx.,	20	0
	Sandstone,	3	6
	Gap (some fakes seen), approx.,	15	0
	Blaes,	2	0
	Fakes and sandstone,	19	10½
	Blaes and ironstone balls,	6	4
	Blaes and ironstone balls, some "mussels,"	3	7
	"Mussel"-ironstone,	0	2
	Blaes with "mussels,"	1	3½
	Blaes with ironstone balls,	1	6
	Shale,	0	3½
	Coal,	0	8
	Blakes and fakes,	9	6
	Shale with "mussels" and fish teeth,	0	3
	Coal,	0	8½
	Blaes and balls with sandstone ribs,	17	9½
	Gap, perhaps,	12	0
Left bank below Castlehill bridge.	Blaes and ironstone balls,	5	4
	Musselband ironstone, very limey, with "mussels," fish teeth, &c.,	0	11
	Ironstone,	0	0½
	Dirty coal,	2 in. to 0	3
	Fireclay,	0	9
	Blaes and Balls with 1 ft. 3 in. sandstone,	6	6½

These are probably the highest beds met with.

The 11 inches "Musselband" lying 7½ feet above the 3 feet 5½ inches coal of this section is a very useful index horizon for this district. It has the same position relative to the thick upper seams of the Coal Measures that the Index Limestone has as regards the Limestone Coals. A similar band is met with near Holytown Station, at a distance of approximately 25 fathoms above the Ell Coal. It may represent the ironstone position at Palacecraig.

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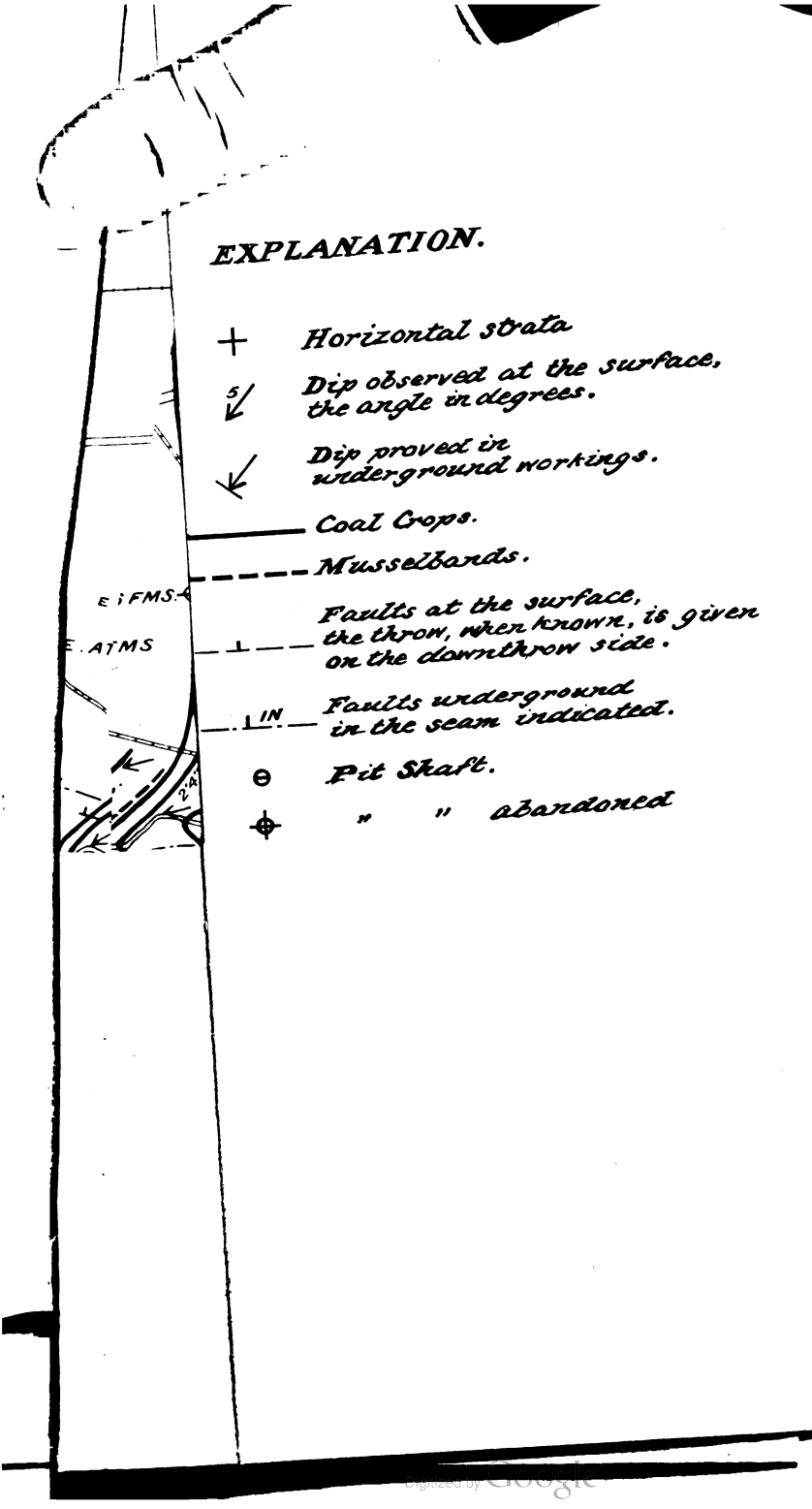

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No. XII.—Variolites from Upper Loch Fyne and Skye.

By G. W. Tyrrell, A.R.C.Sc., F.G.S., Assistant to the Professor of Geology, Glasgow University.

[Read 11th April, 1912.]

Introduction.

With the progress of petrographical research, spherulitic rocks of basic composition are now known to have a fairly wide distribution in the British Isles. Examples have been described by Cole[1] and Sollas,[2] from Ireland; by Groom,[3] from the Lake District; and by Blake[4] and Cole,[5] from Anglesey, to mention only a few occurrences. Scottish examples were first described by Clough and Harker[6] from the Tertiary igneous rocks of Skye, although Judd and Cole[7] many years previously had described altered spherulitic tachylytes or basalt glasses, which now perhaps would be called variolites. Variolites have now been discovered at several localities in the West of Scotland, notably at Ardmucknish,[8] Loch Melfort, and Easdale, in Argyllshire.[9] In Cowal Mr. Clough has described spherulitic rocks, provisionally designated as trachytes,[10] but which, from examination of slides kindly lent by the Geological Survey, may be considered as belonging to the sub-acid glasses and the less basic tachylytes. The latter correspond well with the variolite of Upper Loch Fyne.

[1] (Annalong, Co. Down), *Sci. Proc. Roy. Dubl. Soc.* (1892), vii., 511-519; (Dunmore Head, Co. Down), *ibid.* (1894), viii., 220-222.

[2] (Roundwood, Co. Wicklow), *ibid.* (1893), 99-106.

[3] (Carrock Fell), *Q.J.G.S.* (1889), xlv., 298-304.

[4] *Rep. Brit. Assoc.* for 1888, 410-411.

[5] *Sci. Proc. Roy. Dubl. Soc.* (1891), vii., 112-120.

[6] *Trans. Edin. Geol. Soc.* (1899), vii., 381-389; Harker, *Tert. Ign. Rocks of Skye* (1904), pp. 346-7.

[7] *Q.J.G.S.* (1883), xxxix., pp. 444-465; Cole, *ibid.* (1888), xliv., pp. 300-308.

[8] E. B. Bailey, *Trans. Edin. Geol. Soc.*, vol. viii., p. 363.

[9] Mem. Geol. Sur., *Seaboard of Mid-Argyll* (1909), p. 89.

[10] *Ibid.*, *Geology of Cowal* (1897), pp. 166-171, figs. 39, 40.

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Upper Loch Fyne.

Field Occurrence.—Large boulders of a variolitic basalt were first discovered on Upper Loch Fyne by the Geology Class of Glasgow University during a week-end visit to Inveraray in February, 1912. Many of these boulders, which were practically unworn, were about 12 inches in width, with varying lengths. The margins showed compact greyish-blue non-spherulitic rock, which continued inwards to a depth of 1 inch. Then came variolitic bands on each side about 1 inch in width. The interior was of the same non-variolitic material as the margins. These blocks had evidently been wedged off by wave action from a dyke about 12 inches wide in the near vicinity. After a short search on the shore the origin of the boulders was discovered in a dyke running nearly due E. and W., about 350 yards N.E. of a thick basaltic dyke which runs right across the Strone peninsula,[11] about half-mile N.E. of Strone point.

The variolitic dyke is clearly exposed on the foreshore, and can be followed from the raised beach to low-water mark, a distance of about 20 yards. It intrudes the phyllites of the Ardrishaig series, and is split up into four separate portions (see Fig. 1). Starting from the low cliff of the raised beach (see Fig. 2, Pl. XXXIII.), we first encounter a dyke, 3 feet in width, tapering out to nothing within about 12 feet. This mass is spherulitic at both margins, the spherules standing out on a weathered surface as little nodular bodies about $\frac{1}{8}$ inch in diameter, and ranging up to $\frac{1}{4}$ inch (Fig. 3, Pl. XXXIII.). Where the dyke thins out the whole of its thickness becomes spherulitic, an interior band of spherulitic material, not traceable very far back, joining up with the marginal bands (see Fig. 1, B). The interior of this mass is not at first sight obviously spherulitic, but ill-defined dark spherical patches can be seen on a smoothed or polished surface. These appearances, however, run in bands parallel to the margins, and become less distinct with increasing distance from the margins.

Parallel with this mass is a thin vein or dyke, varying in width from 7 to 4 inches, and tapering out about 20 feet from the raised beach. In this the spherulites are particularly

[11] Shown on 1in.-Sheet No. 37, Geol. Sur. of Scotland.

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noticeable where the vein thins out. Opposite this, and in the same straight line with the two large masses (see Fig. 1, E), is a thin vein about 6 feet in length, 3 inches in width at its thickest part, and variolitic throughout. Following this, towards low-water mark, occurs the largest mass of all, 30-40 feet long, and of a uniform width of 2 feet 6 inches, ending off bluntly to the west. At the western end this portion of the dyke terminates *vertically* in a smooth rounded variolitic surface, which at one place passes under a capping of schist (see Fig. 1, S). Near the schist capping the dyke is profusely spherulitic.

The evidence is therefore clear that erosion has just uncovered the vertical termination of the dyke at this place. This would also explain the irregular course and splitting of the dyke into so many portions.

A further exposure is seen in a small roadside cutting just opposite the shore occurrence. Here the dyke is 3 feet in width, is apparently variolitic on the southern margin only, and penetrates a quartzite of the Ardrishaig series.

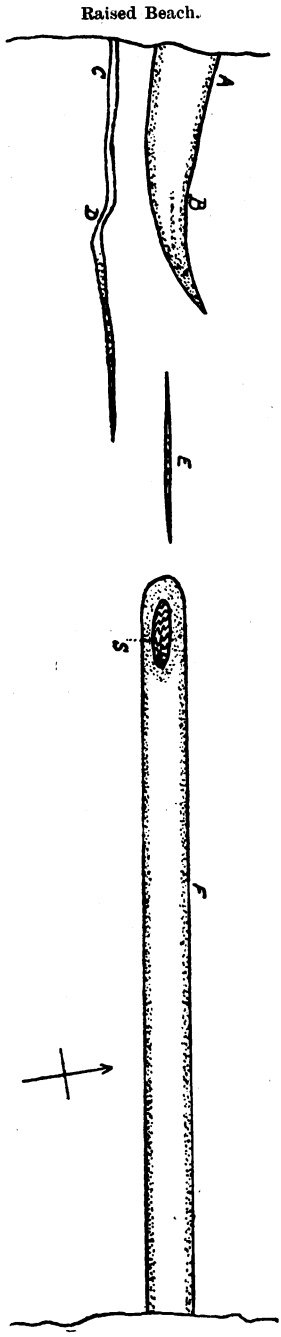

Fig. 1.

Plan of Variolitic Dyke, ¼-mile N.E. of Strone Point. Variolitic portions indicated by shading. S—capping of schist. Width at A, 3 feet 1 inch B, 11 inches; C, 7 inches; D, 4 inches; E, 3 inches; F, 2 feet 6 inches. Total length of section about 60 feet.

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A 3-foot dyke is found on the shore of Loch Shira in the same position as the variolitic dyke as regards the thick dyke of olivine basalt which crosses the Strone peninsula. The rock is a light-grey basalt, which is not anywhere variolitic, but betrays its continuity with the variolitic dyke by the sheaf-like grouping of felspar micolites which it displays in thin section. There can be no doubt but that this is the same dyke, exposed, however, on a deeper horizon.

Skye.

Two occurrences of variolitic basalt, hitherto unmentioned, were discovered during a visit to Skye in April, 1910. One of these was found in a small roadside cutting about 1⅛ miles S.W. of Broadford, near the Allt an t-Sithein, where it crosses the road to Kilchrist. It was sill-like in form, and was associated with a greyish vesicular felsite.[12] I have some recollection that at the time it was considered as belonging to an arm of the composite sill of An t-Sithein.

The second occurrence forms a dyke in the little mass of gabbro intrusive in basalt lavas, about two-thirds of a mile E.N.E. of Sligachan Inn. The rock is excessively jointed, and splits in platy masses parallel with the direction of banding of the variolites.

Petrography.

Variolitic Basalt of Upper Loch Fyne.—Megascopically the rock is compact, aphanitic, greenish grey to dark grey in colour, usually much decomposed, and effervescing freely with acid, although not having the appearance of decomposition. Towards the margin it is slightly vesicular. An occasional small phenocryst is seen, invariably pseudomorphed in calcite.

The varioles have a lighter tint than the groundmass in which they are embedded. They are small, truly spheroidal bodies when occurring singly, and are usually between $\frac{1}{16}$ and $\frac{1}{8}$ inch in diameter, occasionally reaching $\frac{1}{4}$ inch. Commonly they are aggregated and coalescent into parallel bands of

[12] I have unfortunately lost my field-notes of the Skye occurrences, and the meagre details given here are taken from labels on the specimens and from memory.

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confluent varioles, the spherical shape of the individual being variously modified by the juxtaposition of its neighbours. On faces of rock long exposed to weathering the varioles stand out in relief as little pea-like bodies (see Plate XXXIII., Fig. 3).

In thin section the varioles are yellowish in colour, and are set in a pale green groundmass. The colour is frequently deeper in the marginal portion of the variole, the interior being of a paler tint or colourless. Each variole is penetrated by a fine network of small pale-green microlites, not arranged radially, which are much more densely aggregated in the variole than in the adjacent groundmass. It appears therefore that these net-like aggregations of microlites may have been predisposing causes of the formation of the varioles, functioning in much the same way as crystalline nuclei in other spherulitic growths.

In polarized light the varioles are seen to consist of ill-defined, continuous, low-polarizing felspathic substance which gives extinction-appearances suggesting a radial aggregation of fine fibres. The extinction-brush is not a simple cross; there are a number of brushes or rotating bands of extinction indicating the presence of several confluent radiating bundles of fibres within the limits of each variole. The constituent fibres, however, cannot be distinguished in the microscope. As far as can be judged, their extinction is slightly oblique. This is also the case with the felspar of several variolites;[13] and it is thought that the low extinction angles are due to the overlapping of the thin fibres in the thickness of the slide. The analyses of some variolites prove the felspar to be labradorite.

The Becke effect is very hard to determine owing to the number of microlites that throng the variolitic felspars. When a portion of felspar free from microlites is got adjacent to balsam, the effect is still very indefinite, but appears to show a refractive index very slightly greater than balsam. This would suggest that the varioles consist of a felspar near oligoclase or albite-oligoclase; but uncertainty is again introduced by the probable overlapping of fibres.

The pale green microlites that crowd the varioles are rectangular in shape, long, acicular, occasionally pointed or

[13] Clough and Harker, *Trans. Edin. Geol. Soc.*, vol. vii. (1899), p. 385.

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bifid. They show a faint pleochroism in shades of yellow and green, and a maximum extinction of 20°. Hence it is probable that they belong to the group of the amphiboles.

The groundmass in which the varioles are set consists of a pale green, glassy material full of very minute thread-like microlites. There are also a few of the green microlitic amphiboles that crowd the varioles; minute, ragged granules of titaniferous iron ore; and a few microphenocrysts of serpentinized olivine.

In another slide the groundmass is also crowded with the microlitic amphiboles, which are, however, much more decomposed than those in the varioles. The rocks are thoroughly permeated with carbonate and serpentinous alteration products, the varioles, however, remaining comparatively fresh.

Specimens taken from the interior of the dyke are at first sight non-variolitic, but when smoothed or polished show indistinct rounded bodies arranged in bands alternating with material showing no structure whatever. Under the microscope these spherical bodies are very hard to see, but may be distinguished by a very slightly paler tint than the rest of the rock. Under polarized light a fairly well-marked radial arrangement of very fine thin fibres can be seen. These are rather of the nature of a series of mutually interfering curved sheaves or bundles than a simple radial arrangement. Here, in contradistinction to the rock described above, the fibres can actually be seen.

Small serpentinous and carbonated pseudomorphs of olivine and augite are abundant in the interior of the dyke. The augite especially shows very fine idiomorphic outlines, and occurs in small polysomatic masses.

The compact portions of the dyke, in which no spherulitic structures can be distinguished by the naked eye, nevertheless show in thin section numerous sheaf-like groups of felspar microlites in a carbonated groundmass composed of a network of felspar microlites embedded, with euhedral magnetite, in a colourless isotropic base.

The foregoing also exactly describes the non-variolitic continuation of the dyke seen on the shore of Loch Shira.

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Variolitic Basalts of Skye.

The Broadford Occurrence. In hand specimens the varioles are small, $\frac{1}{16}$-inch diameter, very coalescent, and arranged mostly in irregular bands. They have a dark nucleus, surrounded by a thin marginal band of light green material, and are set in a compact, greenish groundmass. A dark band, consisting entirely of closely-packed spherulites, divides off a portion of the rock characterized by a darker groundmass, in which the varioles appear dimly as still darker spots. The varioles are not conspicuous on a weathered surface.

In thin section the varioles are seen to consist of a radiating aggregate of felspar fibres, very thin and fine, and not easily distinguishable except by the composite extinction brushes, which indicate that the varioles are clusters of independent sheaves or bundles of fibres rather than a single radiating mass. Minute dusty specks and microlites are mingled with the fibres, and sometimes have a radiate disposition. The extinction of the fibres is slightly oblique, and their refractive index somewhat greater than that of canada balsam. Hence they appear to be of the same nature as the fibres of the Loch Fyne variolite. The varioles are largely coalescent, and in the dark band above mentioned the forms of the individual spherulites have entirely disappeared, leaving a crowded mass of irregular sheaves or bundles of felspar fibres.

The groundmass in which the varioles are set consists of a dark, indeterminate, crypto-crystalline material containing numerous minute, angular grains of quartz. This lends some colour to the impression that the rock belongs to a composite sill. Some of this quartz is occasionally entangled in the marginal portions of a variole, together with minute ragged specks of magnetite. At the same time, the dusty microlites within the varioles become recognizable as minute grains of augite. A few serpentinous pseudomorphs after a pyroxene occur, one of which forms a nucleus for a variole. This supports the view that the varioles may in some cases not begin to form until crystallization has begun and became rather advanced in the magma; in fact, that they may represent the final crystallization of a residuum, and thus act as "groundmass" to the other constituents.

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The Sligachan Occurrence.—Megascopically the rock consists of bands of small irregular coalescent masses of varioles with very sinuous margins embedded in a dark green compact groundmass. On the weathered surface the varioles appear as small white spots. The rock is full of minute spherical vesicles.

The varioles in this rock are seen in thin section to belong to a remarkable type. Each variole is more or less modified in shape by its neighbours, but is readily seen to be individually spherical. Each is built of a great number of small coalescent radiating bundles, many with a good "extinction brush," and spherical outlines. The margin of a variole is consequently often mammillary, due to the rounded outlines of adjacent small spherules.

Each variole is covered by an immense accumulation of dark microlites. These are arranged in little groups, each consisting of a number of parallel rods. The rods of adjacent groups are not necessarily parallel to the same direction. Within each variole there are generally three prevalent directions, arranged at about 120° to each other. Minor groups of rods may, however, be parallel to other directions, and there is frequently a distinct tendency for the grouping to be parallel to the margins of the varioles. The little rods are black, opaque, and may either be continuous (longulites or crystallites), or made up of a series of little bead-like bodies (margarites). In addition to this type, there are others which consist of two or more spikes growing out from a minute cube or octahedron of magnetite. These have a remarkable resemblance to tetractinellid or hexactinellid sponge-spicules. All the microlites are black, opaque, and may be referred to magnetite. These microlites closely resemble those figured by Judd and Cole in basalt glasses of the Western Isles of Scotland.[14]

The groundmass in which the varioles are set is of a clear, pale yellowish green colour, and has a slight reaction with polarized light. It contains numerous greyish spots (cumulites), and is crowded with the same black microlites as the varioles, although not to the same extent. It is without doubt a slightly devitrified and altered glass. Both groundmass and varioles contain perfectly rounded vesicles of cryptocrystalline silica,

[14] *Q.J.G.S.*, vol. xxxix. (1883), p, 464, pl. xiii., fig. 8; pl. xiv., figs. 2-6.

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which, in the case of the varioles, do not seem to have been nuclei for crystallization.

Origin of Variolites.

Spherulites of all kinds are due to crystallization about a centre, with a radiate arrangement of fine fibres. The condition for their growth is rapid cooling in a highly supersaturated solution. In all the cases described in this paper the fibres consist of felspar, which, in spite of uncertainties, seem to belong to rather acid or alkaline varieties. This tendency allies the variolites to rocks, such as spilites, which are characterized by rather acid plagioclase felspars. The type variolite, that of the Durance, appears to belong to an ancient spilitic pillow lava,[15] and Rosenbusch has described the variolites along with the spilites.[16]

According to Harker, the variolites are closely allied to the spherulitic tachylytes. Cole and Gregory define variolite as "a devitrified spherulitic tachylyte, typically coarse in structure," and regard the well-known rock of the Durance as the type.[17] There are, however, difficulties in this position. The great majority of tachylytes, especially those with spherulitic structures, are restricted to thin films or layers on the margins of intrusive basic rocks; whereas in the Upper Loch Fyne rock, as well as in many others, indistinct variolitic structures are to be found in the interior of a comparatively thick dyke, and the varioles are arranged in bands alternating with non-variolitic layers. The only case of massive tachylyte known is that of Hawaii, where whole lava streams consist of basalt glass; but the lavas of Hawaii are of a peculiar and exceptional nature. They are ejected at a much higher temperature than most basalts, and are extremely liquid. Locally the glassy selvage on intrusive masses reaches a thickness of 7 inches, and one of 22 inches has been recorded.[18] If variolites, therefore, are devitrified spherulitic tachylytes, we

[15] Cole and Gregory, *Q.J.G.S.* (1890), xlvi., p. 314.

[16] Gesteinlehre, 3rd ed. (1910), pp. 423-4.

[17] Cole and Gregory, loc. cit., p. 330.

[18] Loch Scridain, Mull; Heddle, *Trans. Geol. Soc., Glasgow*, vol. x., 1895, 81-85.

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should expect dimensions more comparable to those of the tachylytes we are at present acquainted with.

A basalt, however, may have a considerable amount of glass in its composition, and yet not be a tachylyte. Many of these vitreous basalts have selvages of true tachylyte, which appears generally to have cooled at a rate inimical to the development of spherulites of the degree of perfection of those seen in variolites. The spherulites which have developed usually occur some distance from the actual margin, where the tachylyte begins to lose its distinctive character. It seems probable, therefore, that while some variolites may be derived from devitrified spherulitic tachylytes, many have been developed from less vitreous basalts, which, save for ordinary weathering that has rendered spherulitic structure visible to the naked eye, are not essentially altered from their condition when first intruded. It is perhaps best to retain the term variolite for rocks with a certain megascopic aspect; that is, for basic spherulitic rocks having the spotted, pocked, pitted, or minutely nodular appearance which first suggested the term variolite. With this usage it seems immaterial whether the original glass has or has not suffered secondary changes.

The varioles are generally aligned parallel to the margin of the dyke or intrusive mass in which they are found. The variolites of Mont Genèvre are mostly pillow lavas, in which the varioles are found as a selvage to the pillow-form masses and on every conspicuous surface of division. Towards the interior of the masses the spherulites become closer together, to the exclusion of matrix, but tend also to degenerate into mere sheaves or brushes of plagioclase crystallites.[19] This is almost exactly paralleled in the Upper Loch Fyne dyke.

The alignment of varioles parallel to the margins of an intrusive mass is generally regarded as a phenomenon of flow. The flow-lines in many spherulitic rocks can be seen to pass right through the spherulites, and the latter are clearly subsequent to the development of the flow-lines. There are no flow-lines visible in the rocks under discussion; but it is pretty clear that the varioles developed only after all movement had ceased in the magma. Whilst groups or rows of varioles are often coalescent, there is no indication that individual varioles

[19] Cole and Gregory, loc. cit., p. 313.

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have suffered any deformation as the result of flow. Since the centres of growth of the spherulites occur in planes parallel to the margins of the dykes, the conditions for their occurrence must have some relation to influences set up by the cooling margins. In this respect they are phenomena of the same order as flow-banding, whether by colour, crystallinity, or vesicularity. The physical condition for the growth of spherulites is rapid cooling in a viscous and supersaturated magma. These conditions may be realized by the mode of intrusion of a dyke. The speed of a magma flowing quickly through a fissure is progressively retarded towards the bounding walls. The magma next to the cold walls may solidify quickly enough to form tachylyte, and thus cease to flow. Farther inwards the magma presents conditions of decreasing viscosity associated with gradually, but probably not uniformly, increasing speed of flow. A differential flow may thereby be set up, which may produce planes of shear parallel to the margins in the viscous magma, and give rise to minute differences of physical condition between adjacent strips. These differences would be in respect of gas-content and viscosity, and might give rise to a band of vesicles, spherulites, glass, or crystals, according to the particular conditions of each strip. As viscosity and rate of cooling would be least in the centre of the dyke, it follows that spherulites, if developed at all, would be much less perfect and definite in the interior than towards the margins. Spherulitic structures in bands might also be set up by slight differences of physical condition caused by cooling stresses arranged with relation to any cooling surface, such as the surfaces of the pillow-form masses in the Mont Genèvre lava. In this case the spherulites would be arranged in concentric bands parallel to the cooling surface, alternating with bands showing different structures.

Age and Relations of the Variolites of Upper Loch Fyne and Skye.

The Upper Loch Fyne variolite occurs in a dyke running in an almost due E. to W. direction. This is contrary to the well-known fact that the Tertiary dykes of the West of Scotland have an almost invariable N.W. to S.E. trend. The

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should expect dimensions more comparable to those of the tachylytes we are at present acquainted with.

A basalt, however, may have a considerable amount of glass in its composition, and yet not be a tachylyte. Many of these vitreous basalts have selvages of true tachylyte, which appears generally to have cooled at a rate inimical to the development of spherulites of the degree of perfection of those seen in variolites. The spherulites which have developed usually occur some distance from the actual margin, where the tachylyte begins to lose its distinctive character. ns probable, therefore, that while some variolites ma ived from devitrified spherulitic tachylytes, many developed from less vitreous basalts, which, save wea that has rendered spherulitic structure th eye, are not essentia ed from th n w truded. It is perh retain rio ks with a certain aspect ; bas ic rocks having th cked, p ute appear- ance whic sted th dite is usag it seems hether gl has suffered s anges.

The var nerally argi the dyke c ass in e va lites of M are ich varioles a selv sses on every c face inte of the ma rulit , to exclusion t te ito sheaves or gio is a exactly para The alig ns ive m y-li ou

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have suffered any deformation as the result of flow. Since the centres of growth of the spherulites occur in planes parallel to the margins of the dykes, the conditions for their occurrence must have some relation to influences set up by the cooling margins. In this respect they are phenomena of the same order as flow-banding, whether by colour, crystallinity, or vesicularity. The physical condition for the growth of spherulites is rapid cooling in a viscous and supersaturated magma. These conditions may be realized by the mode of intrusion of a dyke. The speed of a magma flowing quickly through a fissure is progressively retarded towards the bounding walls. The magma next to the cold walls may solidify quickly enough to form tachylyte, and thus cease to flow. Farther inwards the magma presents conditions of decreasing viscosity associated with gradually, but probably not uniformly, increasing speed of flow. A differential flow may thereby be set up, which may produce planes of shear parallel to the margins in the viscous magma, and give rise to minute differences of physical condition between adjacent strips. These differences would be in respect of gas-content and viscosity, and might give rise to a band of vesicles, spherulites, glass, or crystals, according to the particular conditions of each strip. As viscosity and rate of cooling would be least in the centre of the dyke, it follows that spherulites, if developed at all, would be much less perfect and definite in the interior than towards the margins. Spherulitic structures in bands might also be set up by slight differences of physical condition caused by cooling stresses arranged with relation to any cooling surface, such as the surfaces of the pillow-form masses in the Mont Dèvre lava. In this case the spherulites would be arranged in concentric bands parallel to the cooling surface, alternating with bands showing different structures.

AND RELATIONS OF THE VARIOLITES OF UPPER LOCH FYNE AND SKYE.

The Upper Loch Fyne variolite occurs in a dyke running in almost due E. to W. direction. This is contrary to the known fact that the Tertiary dykes of the West of Scotland have an almost invariable N.W. to S.E. trend. The

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E.—W. direction is that taken by the quartz dolerites of the Late Carboniferous in the Central Valley of Scotland. It is natural therefore to inquire whether this dyke may not belong to the quartz-dolerite suite. Most of the dykes in the Strone peninsula, however, have the E.—W. direction. A very thick one, mentioned above, occurs a little south of the variolite, and is worked for road metal where it emerges on the shores of Loch Shira and Upper Loch Fyne. This rock might easily be taken for a quartz dolerite. It is much thicker than the usual run of Tertiary dykes, and has the E.—W. direction. On sectioning, however, it appears to be an ophitic olivine basalt, identical with one of the main groups of Tertiary dykes.[20] Moreover, Mr. Clough[21] mentions that a few of the Tertiary dykes in the Cowal district, immediately to the south, are aberrant in direction, and some have an E.—W. trend. In Scotland Palæozic variolites are as yet unknown, whereas several Tertiary examples have been recorded. In spite of the aberrant direction, therefore, the probability is that the Upper Loch Fyne variolite belongs to the Tertiary suite.

No such doubt attaches to the Skye variolites described in this paper. They belong to the great Tertiary suite of that island. The Broadford occurrence may be a portion of the composite sill of An t-Sithein. If so, it is the first example of these composite sills to be described with a variolitic margin. Much more information as to its field occurrence is needed.

The Sligachan occurrence forms a dyke running in a N.N.W.-S.S.E. direction, and doubtless belongs to the great group of basalt dykes.

[20] Tyrrell. *Trans. Geol. Soc., Glasgow*, vol. xiii., pt. iii. (1909), p. 315.
[21] Geology of Cowal (1897), pp. 139-141.

EXPLANATION OF PLATE XXXIII.

Fig. 2.—Variolitic dyke on shore, ½-m. N.E. of Strone point. The hammer is resting on the portion marked A B in fig. 1 (text). This portion tapers out near the large white patch of lichen. The waterproof lies against the thin band marked C D in fig. 1 (text).

Fig. 3.—Detail of variolitic margin of the dyke, near head of hammer in fig. 1. The coin is a shilling, and the white patch lichen.

I am indebted to Mr. A. Fleck, B.Sc., for these photographs.

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Fig. 2.

Fig. 3.

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No. XIII.—Notes on the Occurrence of Chalcedony, Agate, and Crystalline Quartz in the Lavas of the Campsie Hills. By James W. Reoch, Joint. Hon. Secretary.

[Read 9th May, 1912.]

At odd times in past years I have noticed the occurrence of chalcedony, agate, and crystalline quartz at different spots in the lavas of the Campsie Hills; and as the evidence accumulated I was interested, on linking it up, to find that so far as my observations went these occurrences were all confined to one horizon. It may be of sufficient importance now to record this more particularly; especially as past references to the occurrence of these minerals in the Campsie Hills appear to be more or less vague; and further, as in the recently published Memoir of the Geological Survey on "The Glasgow District," to which I had been looking for fresh observations on the subject, the vesicular character here and there of the lavas is barely referred to, whilst no space at all has been found for any allusion to the mineral contents of their cavities.

Dr. John Young in his "Geology of the Campsie District" states that "in the traps of the Campsie Hills proper crystallized minerals are not very common; such specimens as are met with consist of quartz and calcareous spar, with occasionally an agate filling up cavities in the rock."

Heddle in his "Mineralogy of Scotland" records amethyst as occurring "near the road from Campsie to Fintry"; also that agates occur "occasionally in the Campsie Hills, and in rifts in the hills near Corrie, Kilsyth."

In the "British Association Handbook (1904)," on the "Geology and Palæontology of the Clyde Drainage Area," the Campsie Hills are mentioned as a locality for quartz crystals, but not for agate or chalcedony. Opal is recorded in Corrie Glen.

Mr. Robert Dunlop, of this Society, has informed me of the occurrence of agates near the reservoir at the head of Corrie Burn.

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Goodchild, in the "Royal Scottish Museum Guide to the Collection of Scottish Agates," notices that "very few agates, and these imperfectly formed, have been obtained from basalt lavas," and "in Scotland at any rate these agates are rarely found except in rocks of Devonian age."

Greg and Lettsom, in their "Mineralogy," record that "Kilpatrick quartz of Thomson occurs in the amygdaloid of the Kilpatrick Hills near Dumbarton in small, spherical masses, white and translucent, consisting of fibrous and radiated crystals terminated at their outer extremities," to which I shall refer later on.

As regards my own observations, I have now traced a horizon on which these minerals occur, running east and west along the south face of the Campsie Hills at the Ordnance level of about 1100 feet, from Brown Hill, north-east of Milton, to Slough Muclock, at the landslip above Lennoxtown, a distance of about 2½ miles. The lavas are here mapped by the Survey as basalts of Jedburgh type. At this particular horizon—I am not prepared to say it is confined to one flow—the lava appears to be prevalently amygdaloidal. The amygdales have a fair range in size, from microscopic up to 2 inches and more in diameter, the larger ones being infrequent; and the majority of them, so far as my examination of the ground here goes, seem to be filled with calcite, none of them bearing zeolites. The vesicles weather out conspicuously on exposed surfaces as well-rounded cavities, and the somewhat decomposed rock breaks away readily in large blocks under the hammer. A good specimen got at a small escarpment on Brown Hill shows a geode from a rough-walled cavity, 2 inches in longest diameter, lined with chalcedony of a grey colour showing banded agate structure, overgrown with clear quartz crystals. Further west, keeping the same level, on a rocky prominence near the east branch of the Forking Burn, pale bluey-grey and white chalcedony occurs plentifully, filling rifts and in vesicles, and showing agate structure occasionally; and here also, where space has favoured, it is overgrown with clear crystalline quartz. A slice of the rock from this locality shows an agate of microscopic size in position, as well as other vesicles. In the section exposed in

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this, and also in the west branch of the Forking Burn, crystalline quartz and red-spotted agate occur in cavities; and tracing the horizon further west, at a little projecting cliff at Knockybuckle, again pale bluey-grey chalcedony occurs in rifts. Still further west, in the burn descending just east of Slough Neach, and at the same level, finely-formed bipyramids of clear quartz set on calcite were found coating cavities. In Slough Neach itself, and enveloped in the felsite sill there, a mass evidently of the same lava appears, much decomposed, and characterized by containing numerous vesicles, mainly filled with calcite, but occasionally with clear quartz crystals set on the calcite. A specimen obtained here shows a drusy cavity of about 1 inch in diameter lined with calcite overgrown with quartz in bipyramids; and another drusy cavity, 2 inches in diameter, containing the same minerals was seen in position close by. Between this point and Slough Muclock I have not yet had an opportunity of following out particularly the ground, but the evidence from fallen blocks shows that the rock still persists with the same character. Indeed, the specimen which first drew my attention to the occurrence here of this crystalline quartz lies on the top of a "drystane dyke" which runs up the hillside below the escarpment; it has formed part of a larger druse than any I have yet found in place. Lastly, at Slough Muclock, in the blocks fallen from the precipice above the landslip, numerous specimens of chalcedony of a pinkish colour in veins and cavities, some of it showing agate structure, as well as crystalline quartz, are to be found.[1]

In a scree slope beneath the escarpment east of Slough Muclock I picked up a piece of lava containing a vein of what I take to be the Kilpatrick quartz of Thomson, already referred to as described by Greg and Lettsom, as it conforms to their description. It is quite reasonable to assume that this has fallen from the cliff above, although I have not yet been able to locate any vein in position. It would be interesting to know if this specimen has the same character as the radiating quartz crystals recorded (on p. 149) in the recent

[1] The localities mentioned will be found on the 6-inch Ordnance Map sheet xxviii., N.W.

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Memoir on "The Glasgow District" as occurring near High Craigton on the Kilpatrick Hills. The specimen is very beautiful viewed with a lens, and still more so in microscopic section under crossed nicols, each spherule showing a black cross of extinction along with brilliant interference colours.

A nodular mass of quartz crystals got near the same locality is also of interest. The quartz is here associated with hæmatite, which coats some of the crystals a characteristic red colour, and which occurs also both on the outside as well as *enclosed in* some of the quartz crystals in small black disc-shaped spots of about $\frac{1}{2}$ mm. in diameter, thus showing its contemporaneous formation.

I have thought it of interest thus to place briefly on record the occurrence of these minerals, even although they must have been observed by many others before me. I do not know to what extent they may be found elsewhere in the Campsie Hills, but the references already quoted would point to their not being very common. I make no attempt to explain what is the meaning of their formation here. We are told, however, in the Survey Memoir (pp. 126-7) that "setting apart the quartz-dolerite intrusions and also the decomposed west-north-west dykes, all the igneous rocks" of Glasgow district, "both lavas and intrusions, are referable to a magma of alkali character, bordering upon sub-alkali." Further, Mr. G. W. Tyrrell at a recent meeting here accounted in a general way for the prevalence of agates in the Old Red lavas of the east of Scotland, as contrasted with zeolites in the lavas of the Kilpatrick Hills, broadly from the fact that the former are a calcic whilst the latter are an alkaline series of lavas. It is all the more interesting then to notice that these forms of pure silica should also occur in the alkaline lavas of the Campsie Hills, whilst zeolites, so far as I know, are not here markedly, if at all, predominant over them. It is true that the agate structure in specimens found by me in the Campsie Hills, though undoubted, is imperfect, and not to be compared with that developed in specimens from the Old Red lavas of the east of Scotland.

The whole question of the formation of minerals in rock cavities, and of the order of formation of different minerals in

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the same cavity, is one of surpassing interest. It is a subject still wrapped in some obscurity, and one which geologists generally seem to avoid treating in any detail. Goodchild[2] remarks on the curious feature connected with the modes of occurrence of zeolites, that contiguous cavities may contain totally different minerals, and yet that all must have been filled about the same time by solutions derived by the same means from the self-same rocks. In his remarks on the agates of the Old Red augite-andesites[3] he notices that after the deposition of the outer celadonite layer in a cavity this may be succeeded by a zeolitic layer, which may fill the cavity to the exclusion of pure silica; but that more often the zeolitic layer terminates at an early stage and is succeeded by chalcedony. If the agate stage has been reached and the deposition of chalcedony has not been continued, then the cavity within the chalcedonic layers becomes coated with crystals of quartz, the deposition of which may go on until the cavity is nearly or quite filled. Where the centre remains unfilled it is not unusual to find crystals of calcite perched upon the faces of the quartz crystals. (In the Campsie specimens, already noted by me, where quartz and calcite occur in the same cavity the quartz crystals are set on the earlier-formed calcite.) Goodchild, of course, regarded the agates as derived from the decomposition of these eruptive rocks by water percolating from the surface. Harker,[4] again, in discussing the amygdaloids of the Tertiary basalts of Skye (which are classed in the sub-alkali group), while attributing the filling in of the cavities partly to the agency of surface waters, takes also into account, as most geologists now do, effects which "may be *due to the action of water of volcanic origin* held in the vesicles, and otherwise, in the lavas themselves, and possibly, too, of other mineralising agents"; and he further infers that alteration due to the latter causes has been effected almost wholly within a quite limited time immediately following the extrusion of the lavas. If the cavities

[2] *Trans. Geol. Soc. Glasgow*, vol. xii., supplement. "The Natural History of Scottish Zeolites and their Allies" (1903), p. 6.

[3] Royal Scottish Museum Guide to the Collection of Scottish Agates. Reprint 1907, pp. 9 and 18.

[4] A. Harker on "The Tertiary Igneous Rocks of Skye" (1904), pp. 41 and 46.

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were filled by zeolites and other minerals during the cooling of the lavas the earlier-formed minerals must have crystallized at higher temperatures than those which followed. Quartz and calcite thus are noted as being the earliest-formed minerals in the cavities in which they are found, as might be expected; then follow chloritic minerals, the zeolites coming later: which brings out a different and reverse order from Goodchild.

The formation of all these minerals in rock cavities, showing such variety of species and such beauty of crystalline form, is I think one of the most admirable works of Nature; and there still remains here a wide field for future research by mineralogists.

(NOTE.—Specimens from all the localities mentioned were exhibited at the meeting at which the foregoing was read.)

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D. Gourlay, del.
Posidonomya corrugata, Ether. (natural size), Boghead, near Hamilton.
From a Specimen in Kelvingrove Museum.

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No. XIV.—On the Distribution of Posidonomya corrugata, Ether. Jun., in the Carboniferous Limestone of the Glasgow District.

By Peter Macnair, F.R.S.E., F.G.S., and Harry R. J. Conacher.

[Read 15th February, 1912.]

Introduction.

When recently examining the Lower Carboniferous Limestone Series as seen in the different burn sections at Corrieburn, we discovered immediately above the upper post of the Hosie limestone a dark shale which is literally crammed full of the shells of *Posidonomya corrugata*. Upon examining the various records giving the geological and geographical distribution of this species in the Glasgow neighbourhood, we were much struck with the conclusive manner in which the evidence went to show that *P. corrugata* is particularly well developed in certain beds towards the top of the Lower Limestone Series. The recent advances that have been made in the correlation of the different members of the Lower Limestone Series have also made it possible to show with more exactness that beds rich in *P. corrugata* seem to occupy fairly well-defined geological horizons. We also believe that the occurrence of this fossil upon certain definite geological horizons has an important bearing upon the question that has again been raised as to the position of the Hosie limestone in the East Kilbride district, and for these various reasons we have ventured to bring the matter before the Society.

Until the recent publication of the memoir on "The Geology of the Glasgow District,"[1] the exact position and relationships of the different limestones and other strata seen at Corrieburn do not seem to have been very well understood. Thus we find the late Dr. John Young, in his "Geology of the Campsie District,"[2] saying, "The relationship which the Corrieburn beds bear to those seen further west in the Campsie Valley has not

[1] *Mem. Geol. Sur.*, "The Geology of the Glasgow District."

[2] *Trans. Geol. Soc. Glas.*, vol. i., third edition, p. 46, 1894.

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yet been very clearly established. At one time I thought that they might be higher in the series, but since I have seen equivalent strata in other parts of the country, I am inclined to place them in a lower position, and it is very probable that they are in that of the main limestone series, or of beds still lower in the system. From the occurrence of *Naiadites crassa* of Fleming in the Corrie beds, I am inclined to regard them as of the same age as the thick limestone at Beith, in Ayrshire, and at Cult Hills, in Fifeshire. In all of these localities this shell is very abundant, and I have never met with it in any other horizon in our limestone strata. From the similarity of many of the corals and other shells in the Corrie limestone to those found in the limestone of the Bathgate Hills, I would also connect them as of one age, especially as the two groups are further marked by the occurrence of contemporaneous traps and ash beds at their base." In the memoir to Sheet 31[3] the officers of the Survey give the following description of the Corrieburn section:—"The lowest of the three limestone groups is only exposed here in three different places, where its strata peep out against the large fault which flanks the Campsie Hills. These are most typically seen in the Corrie and Queenzie Burns and their tributaries between the two parallel faults. There, immediately overlying the tuffs of the cement-stone group, a thin white concretionary limestone occurs, full of encrinite stems and corals. A few fathoms higher a thick bed of blue limestone has been extensively quarried. It represents the Hurlet limestone. Not more than 10 feet of alternating beds of limestone and shale are visible, the base being never exposed. For at least 50 fathoms in ascending order the succeeding strata consist more or less of blue clay-shales, with nodules and bands of clay ironstone, with at least three thin bands of limestone, known as the 'Hosie's.' One of the above-mentioned burns exposes a cliff of from 80 to 100 feet of these blue clays, with layer after layer of clay ironstone nodules. Towards the upper limit of the Hosie's limestone the intervening strata contain several beds of sandstone. One band of shale is crowded with a *Lingula*." These two quotations contain, so far as we are aware, the only definite statements that, up till the recent

[3] *Mem. Geol. Sur.*, explanation of Sheet 31, p. 28, 1879.

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publication of "The Geology of the Glasgow District," had been made regarding the stratigraphical position and correlation of the different strata seen in the Corrieburn section. From these it will be seen that Dr. J. Young considered that they could not be correlated with the Campsie strata, and he inclines to favour the view that they should be placed on a lower horizon than the Campsie limestones. On the other hand, the officers of the Survey correctly identify the thick bed of limestone worked in the Corrieburn section as the equivalent of the Hurlet. In the Survey Memoir just issued this identification is corroborated, and further details are given regarding the correlation of the different beds exposed at Corrieburn. The reader is referred to the memoir for details; we only here give a summary of the views stated therein. We reprint from the memoir the following table, so as to add perspicuity to our remarks:—

	Feet.
Black Oily Shale, with *Lingula*,	40
Limestone, with *Bellerophon* (HOSIE LIMESTONE) top of the Lower Limestone Group,	2
Strata, with Thick Yellow Sandstone (Hosie Sandstone),	—
Black Shale, with Septarian Ironstone Nodules, marine fossils near base,	70
Limestone, partly Marine, with Encrinites, partly Dolomitic, Oolitic, with Entomostraca (BLACKHALL LIMESTONE),	—
Strata—Black Shales and Sandstones, with Ironstone Band,	150
HURLET LIME { Upper Hard Band, / Calmy Band, / Lower Hard Band,	15
Large growth forms of Brachiopods and Mollusca. Base of the Carboniferous Limestone Series,	
Strata, with thin Coal,	—

CORAL LIMESTONE.

Strata passing down into volcanic detritus.

The officers of the Geological Survey point out that throughout the Campsie, Lennoxtown, and Corrie area a definite succession of the following recognisable horizons has been established:—

6 Bellerophon Limestone (Hosie Limestone).
5 Yellow Sandstone (Mount Hullie and Hosie Sandstone).
4 Black Shales, with Septarian Nodules.
3 Blackhall Limestone.
2 Black Shales, with Sandstone, in Corrie district.
1 Hurlet Limestone.

After describing the limestones in the Campsie neighbourhood, it is remarked that the section of the Lower Limestone at

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Corrie differs from those already described only in the beds that immediately underlie the Hurlet limestone, and this we are quite willing to corroborate. The Hurlet coal has dwindled down to a few inches at Corrie, but there can be no doubt as to the identity of the alum shale at Corrie with that at Campsie, as it holds exactly the same fauna. It is beyond the scope of the present paper to discuss in detail the correlation of the strata that lie below the Hurlet coal at Corrie with that of the Campsie district, and, though it is frankly admitted that at first inspection the strata seem to be totally different in the two areas, yet a closer examination convinces us that they are undoubtedly the equivalents of the limestones which lie immediately below the Hurlet coal as seen in other parts of Lanark, Renfrew, Dumbarton, and Ayrshire. This view seems to be confirmed by the presence of the thick band of coralline limestone, and by the presence at the base of the section of the well-defined band of *Naiadites crassa*.

Whatever doubt there may be as to the correlation of the beds below the Hurlet coal, there cannot be any regarding the beds that lie above it. The Hurlet limestone has indeed increased in a very short distance from 4 feet in thickness to 15 feet, but this is nothing exceptional. In the type locality at Hurlet we find a similar phenomenon taking place, for at the village of Hurlet the limestone averages about 4 feet in thickness, while at Nethercraigs, only 3 miles distant, it rises to some 30 feet in thickness, and there cannot, we think, be any reasonable doubt as to the identity of the limestones at the two localities. It is also quite clear that the limestone exposed in the bed of the western burn at the base of the great scar of shales and ironstone nodules is the Blackhall limestone, and identical with that seen in the same position further to the west in the Campsie district. Above the Blackhall limestone, separated from it by the black shales and Hosie sandstone, comes the Hosie limestone. It is exposed in the Corrieburn section in a small stream a little to the east of the Blackhall limestone. This limestone, which is in two beds, has sometimes been called the Bellerophon limestone, because it contains large numbers of a small species referable to that genus.

Above the Hosie limestone lies the bed of black shale con-

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taining *Posidonomya corrugata* which it is the particular object of this paper to describe. The surface of the black shale is simply covered with the shells, which vary in size from 1 up to 6 inches in breadth. They have been preserved in iron pyrites, and their bright metallic lustre makes a striking contrast against the dark shale. So far as we have been able to observe, this is the only species which occurs in this particular bed.

We have already pointed out that we consider the occurrence of this bed to the north of Glasgow has an important bearing upon the question that has again been recently raised as to the position of the Hosie limestone in the East Kilbride district, and it is necessary that we should here briefly state the two views that have been held upon this matter by Mr. Neilson and the officers of the Geological Survey. As Mr. Neilson's views were enunciated about a year previous to those of the Survey, we may consider them first. His paper was read before the Society in December, 1872, and in it he deals with the section of Carboniferous Limestone near Busby, and describes the well-known Thornton, Thorntonhall, Braehead, and Phillipshill Quarries.[4] The following extract from his paper will best express his opinion as to the stratigraphical position of the strata seen in these quarries and his reason for assigning them that position:—"The highest shale in the section at the quarries contains many well-preserved fossils When first we visited it, being under very favourable circumstances, many fine and rare specimens were found, among which may be mentioned nearly a dozen *Goniatites*, about the same number of *Leda longirostris* and *Nautilus subsulcatus*, besides specimens of *Euomphalus tuberculatus* and others. On comparing the group of fossils with that of the list from the Hosie limestone series on the south Hill of Campsie given by Mr. John Young in his paper on 'The Geology of the Campsie District,' there can be no doubt that the beds are on the same geological horizon, many of the fossils being alike in both, and a large entomostracan (*Polycope Youngiana*) being, so far as hitherto observed, confined to this same series of beds.

"The locality on the south Hill of Campsie was long a

[4] *Trans. Geol. Soc, Glas.*, vol. iv., p. 123, "On some sections of Carboniferous Limestone near Busby.

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favourite one with our local geologists, and in the admirable catalogue of carboniferous fossils of the West of Scotland by Messrs. Young and Armstrong it is mentioned with an expression of regret that the shale heaps are now obliterated, and directions are given to look for future pit sinkings along the south hill. At that time the authors did not expect it to appear about 15 miles to the southward.

"Many of the fossils in this shale are converted into iron pyrites, and have a very fine appearance, especially when first laid open. This change does not seem to have taken place indiscriminately or by chance, but according to species; some of the species seem to have had a peculiar affinity during fossilisation to this sulphuride, while with others it is wanting.

"The distance between the Hosie and main limestones at Campsie is about 22 fathoms, and at Carluke 19 fathoms, and from the fact that there are three or four ironstones wrought under the Hosie limestone at Campsie, we are of opinion that the missing strata here should be placed between the lowest ironstone and the three post limestones."

From this quotation, then, it will be seen that Mr. Neilson regards the top limestone seen in the Busby Quarries as the equivalent of the Hosie band of the Campsie district. This, of course, would necessitate the placing of all the limestones above it in the Upper Limestone series, including the Calderwood cement-stone group. In the "Carboniferous Fossils of the West of Scotland" the Calderwood cement-stone group is placed in the Upper Limestone Series. But in the "Catalogue of Western Scottish Fossils," published at a later date, it is curious to note that in no instance is the cement-stone group referred to a definite horizon. It seems as if the compilers of the catalogue were dubious as to whether they should be placed in the Upper Limestone Series, with Mr. Neilson, or in the Lower Limestone Series, with the officers of the Survey. In the memoir to Sheet 23, published in 1873,[5] in the section dealing with the East Kilbride district, the Survey place the Busby Quarries group of limestones in the Lower Limestones of the Lower Limestone Series, and the cement-stone group in the Upper Limestones of the Lower Limestone Series, so that they differed from Mr.

[5] *Mem. Geol. Sur.*, explanation of Sheet 23, p. 28, 1873.

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Neilson as to whether the cement-stone group should be placed in the Upper or Lower Limestone Series. No attempt, however, is made by the Survey to correlate in detail the limestones of the East Kilbride district with those in other parts of the West of Scotland. But it is worthy of note that the cement-stone band of East Kilbride is correlated with the first Kingshaw bed of Carluke district. In the recent re-survey of the East Kilbride district a considerable advance was made, because it was found possible to correlate in detail the limestones of that area with those of the typical Hurlet locality. The limestones in the Busby Quarries were identified as the Blackbyre and Hurlet, the Hurlet corresponding to Mr. Neilson's Hosie; the Blackhall, with all its characteristic features, was found in its proper position; the Hairmyres was identified with the Hosie; while the cement band is considered as lying at the top of the Lower Limestone Series. It is the purpose of this paper to show that in the East Kilbride district there is a well-marked band of shale lying above the cement-stone full of *Posidonomya corrugata*, and that this band can be correlated with the *P. corrugata* band of the Kilsyth and Campsie districts, thus confirming the correlation made by the Survey officers.

Posidonomya corrugata, Ether.

The earliest notice that we have of the occurrence of *P. corrugata* in the Carboniferous rocks of the west of Scotland is that made by Messrs. Young and Armstrong in their paper on "The Carboniferous Fossils of the West of Scotland."[6] At page 45 it is referred to the genus *Anomia*, and is named *Anomia corrugata*, Etheridge MS. The following note is appended:—Rare. Upper Limestone, Boghead, in thin band of limestone contained in upper black shale, Linn limestone, Dalry. It is further noted, under the head of localities, that at Kirktonholm, near East Kilbride railway station, whole colonies of *Anomia corrugata* occur in a shale, along with *Leda attenuata* and a few other bivalves. In 1873 Mr. Etheridge, in an appendix to the memoir on Sheet 23,[7] describes the specific characters of the shell, makes a number of observations

[6] *Trans. Geol. Soc. Glas.*, Supplement to vol. iii., 1871.

[7] *Mem. Geol. Sur.*, explanation of Sheet 23, p. 103.

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upon it, and gives a list of localities where it has been found in Sheet 23. His description is as follows:—

"*Sp. Chars.*—Irregularly ovate, variable, compressed, occasionally assuming an oblique form, at times narrowed towards the beaks, and expanded towards the ventral margin; beaks in the ovate forms nearly central, in the oblique forms nearer the anterior end, sharp, prominent; anterior end rounded; posterior end somewhat truncated; the distinguishing character of the shell is the very irregular concentric corrugated wrinkles which cover the surface; in nearly all adult specimens these are supplemented by a variable number of strong, wrinkle-like ribs, which radiate from the beak to the ventral margin on the central portion of the shell only, leaving the anterior and posterior ends merely covered with the concentric markings; shell very thin."

Mr. Etheridge says *P. corrugata* was highly gregarious, and at certain localities, in beds of the Lower Limestone Series, more especially those of the Calderwood cement-stone series around East Kilbride, very common. He gives seventeen localities where *P. corrugata* has been collected in the East Kilbride and Carluke districts, and all these, with but two exceptions, are from horizons either immediately above or below the Calderwood cement-stone.

Both *Posidonomya corrugata* and *P. becheri* appear to have favoured certain physical conditions when they were enabled to spread over large areas in great numbers. Thus Mr. R. G. Carruthers, of the Geological Survey, has recently discovered a band of *P. becheri* in Calder Glen, East Kilbride, below the main limestone associated with *Pterinopecten papyraceus*. Since this paper was written we have also found the same shell in considerable numbers in the shale overlying the Blackhall limestone of the Campsie district, this being the band whose stratigraphical position in the Campsie and East Kilbride districts has been already discussed.

The Posidonomya corrugata Bed in the Campsie and Kilsyth District.

Though we have only recently noted the occurrence of the *P. corrugata* band at Corrieburn, yet its existence on a certain

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definite horizon in the Campsie and Kilsyth district has long been known, as will be seen from the foregoing part of this paper. Previous to the recent revision of the Campsie area, the succession of the Lower Limestone Series to the north of Glasgow was not very well understood, the true Hosie limestone at the top of the Lower Limestone series being often mixed up with the Blackhall limestone, which lies upon a lower horizon, and whose lithological and palæontological characters are quite different from those of the Hosie limestone. The Hosie limestone to the north of Glasgow is in two bands which come close together. The lower, which is about a foot thick, is similar to the upper, which is a hard grey limestone, and full of the remains of a small *Bellerophon*. So far as we are aware, the true Hosie limestone does not appear in the South Hill of Campsie, the highest strata seen on that hill being the Hosie sandstones, which lie immediately below the Hosie limestone. The limestone which is named the Hosie limestone by Dr. Young in his "Geology of the Campsie District"[8] in the journal of bore passed through in sinking a pit near the summit level of the South Hill, and called the Black or Hosie limestone, is not the Hosie limestone proper, but the Blackhall limestone. This is of considerable importance, as it was clearly from the Blackhall limestone horizon that Dr. Young obtained the assemblage of fossils of which he gives a list in the "Catalogue of Western Scottish Fossils." It was upon the supposed similarity of this fauna with that found in the Upper Shales of the Thorntonhall Quarries that Mr. Neilson identified the top limestone of these quarries with the Hosie limestone. An examination of the fossil lists from various localities in the Carluke and East Kilbride district, however, reveals the fact that the species cited by Dr. Young as being among the more typical forms from the South Hill, Campsie, also occur on a horizon immediately above the Calderwood cement-stone group, so that they cannot be claimed as peculiar to the Blackhall limestone horizon. But this matter will be further referred to when we come to consider the East Kilbride district. It now remains for us to show that the *P. corrugata* band to the north of Glasgow occupies a well-defined and constant position above

[8] *Trans. Geol. Soc. Glas.*, vol. i., third edition, p. 61.

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the top Hosie or Bellerophon limestone, and thus marks the upper limit of the Lower Limestone Series. Beginning at the most easterly exposure, we find that *P. corrugata* has been recorded from the river Carron, above Mill, $1\frac{1}{4}$ miles west of Denny. We have not been able to identify the exact position of this locality, but as it is recorded in Explanation to Sheet 31 as being in the shales and nodules above the Hosie limestone, we have no doubt that it occupies the same geological horizon as those about to be described. The next locality is in the burn below Drumressie, $2\frac{1}{4}$ miles east-north-east of Kilsyth. At this point the exposure is somewhat obscure, but specimens in a somewhat badly preserved condition have been collected by us. There seems, however, to be no doubt that here again *P. corrugata* occurs in the shales overlying the Hosie limestone. About a mile further to the west, at Brockieside, the band has been found on exactly the same stratigraphical position. So far as we are at present aware, the most westerly exposure of this band to the north of Glasgow is that to be seen in the Shields Burn, about a mile to the north of the Milton of Campsie. The stratigraphical succession from the thin, sandy, encrinital band, about 10 fathoms above the Hurlet limestone, up to the Hosie limestones is exceedingly well displayed in this burn, and in the shales above the Hosie limestones the *P. corrugata* band, though much weathered, has been distinctly traced. The band has much the same appearance here as that seen at Corrieburn, but, as has been observed, the shells are in a much less perfect condition of preservation. The pyrites in which they are preserved has been altered, and the bedding planes of the shales have been coated with fine secondary crystals of gypsum.

In the neighbourhood of Lennoxtown *P. corrugata* has been recorded from quite a number of localities, both on the north and south Hills of Campsie. But at these localities the shell is found at a much lower stratigraphical position than those which have already been described. Specimens of *P. corrugata* are recorded by the Survey as having been found in a "burn passing Bencloich Mill, above wall forming limit of cultivated ground N.E. of Lennoxtown." We are unable to identify this locality, but it seems most likely that the shell was here

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found in the alum shale below the Hurlet limestone. We have been able to prove that *P. corrugata* occurs in the alum shale below the Hurlet limestone both at Boyd's Burn Mine and in Glen Wynne, on the South Hill. At the former locality it was found in the alum shale put out with the lime. At the latter there is a very clear section from the alum shale to the base of the Craigenglen series, showing what we believe to be the representatives of the Hollybush, Blackbyre, and Baldernock limestones. *P. corrugata* makes its appearance for the first time in the alum shale along with the characteristic fauna of that horizon.

The Posidonomya corrugata Band in the East Kilbride and Carluke Districts.

We now pass to a consideration of the occurrence of this band in the East Kilbride and Carluke districts. We have already in this paper pointed out the different interpretations that have been advanced of the succession of the Carboniferous Limestones by Mr. Neilson and the officers of the Geological Survey, and we must frankly state that, so far as our own observations have gone, they completely confirm the general conclusions of the Survey. On evidence which need not here be discussed, we believe that the strata seen in the Thorntonhall Quarries range from the Hurlet limestone at the top to the base of the Blackbyre limestone. Fairly continuous sections from the Hurlet limestone to the *P. corrugata* band are shown in the Kittoch Water and in Calderwood Glen, and these will be briefly described for the purpose of fixing the position of the *P. corrugata* band. Beginning at the main post limestones on the Kittoch Water, where it is exposed at the waterfall near Arrotshole, we have above the main post the Hurlet limestone, the succession being practically the same as that seen in the Thorntonhall Quarries. About 100 yards further up the stream is crossed by the Blackhall limestone, and above this comes a series of shales and thin ironstones. The stream now winds through a plantation, and on its left bank are seen shales, with occasional courses of grit and bands of clay ironstone, which pass upwards into a calcareous grit, which marks the position of the main Hosie limestone. Crossing the East Kilbride Road,

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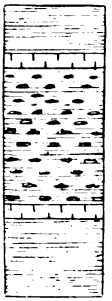
we find the Calderwood cement-stone series exposed in the burn, and in a few small sections that are still seen at the Burnbrae Quarries. The section is as follows:—



P. corrugata Band.

Cement Limestone, 14 ins.

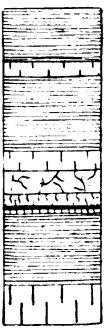
Shales, with Ironstone Nodules, 10 ft., 12 ft.

Encrinital Limestone.

Fossiliferous Limey Shales, grading laterally into Limey Sandstones.

Section of Calderwood Cement Group as seen at Burnbrae (Kirktonholm), near East Kilbride.

An equally clear section is exposed in Calderwood Glen. About 350 yards below Calderwood Castle the Hurlet limestone is succeeded by the Blackhall limestone, which passes upwards into a series of shales, with bands of ironstone (the Crossbasket ironstones). Near the castle these are succeeded by a thick group of sandstones and shales, which dip up the stream at a low angle, and are succeeded above the waterfall by the main Hosie limestone. The Hosie limestone appears at the base of the section near the level of the stream, and in the cliff above it there is a fine section of the Calderwood cement series, as shown in the following diagram.



Shales, with *P. corrugata*.

Cement Stone.

Shales, 6 feet.

Encrinital Limestone, 14 ins.
Fireclay.
Limestone, with Rootlets.
Coal.
Ironstone.

Marine Shales, with *P. corrugata*, *Leptodomus costellatus*, *etc.*

Main Hosie.

Section of Calderwood Cement Stone Series as seen in Calderwood Glen.

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The Calderwood cement-stone has been worked at the following localities:—Calderside, Binnie's Holm, Brankumhall, Capelrig, Black Braes, Limekilns, Stuartfield, Kirktonholm, and Burnbrae, and in these and in numerous natural sections, wherever the cement-stone is exposed, it is invariably accompanied by the *P. corrugata* band, which in this district marks a well-defined horizon.

The *P. corrugata* band has also been traced at several localities in the Carluke district at what we consider to be close upon the same horizon as it is found in the districts of Campsie and East Kilbride. In the Explanation to Sheet 23 it was pointed out by the Survey that the East Kilbride cement-stone is the equivalent of the Calmy limestone that overlies the first Kingshaw bed of Carluke District, and both the Lingula limestone and the shale that underlie it are rich in *P. corrugata*. Specimens have been collected from this horizon at the following localities:—Fiddler's Burn, about 1¼ miles east-south-east of Carluke, in the shale below the Raesgill Ironstone, and at Hallcraig Bridge, on the left bank of Jock's Burn, about 1 mile west of Carluke, in the shale between the first Kingshaw lime and the Lingula lime.

Summary of Conclusions.

(1) That immediately above the top Hosie of Corrieburn and the Campsie district generally, and that in the Denny, Kilsyth, East Kilbride, and Strathaven districts in relationship to the limestones referred to there can be traced a bed of black or grey shale characterised by the great abundance of *Posidonomya corrugata*, Ether.

(2) That both the stratigraphical and other palæontological evidence shows that this bed of *Posidonomya corrugata* marks the position in all these districts of the top Hosie limestone of the Campsie district.

(3) That the characteristic fauna discovered by John Young in the shales above the Blackhall limestone of the South Hill of Campsie also occurs above the Hurlet of Thorntonhall and the Calderwood cement-stone series of East Kilbride. But it seems likely that this fauna is limited to the Lower Limestone Series, and does not pass into the Upper Limestone.

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(4) That the aforementioned fauna is associated with species that range from the top to the bottom of the Limestone Series.

(5) That *Posidonomya corrugata* is a comparatively rare shell on other horizons than that immediately above the top Hosie.

(6) That both the palæontological and stratigraphical evidence confirms the correlation made forty years ago by the Geological Survey between the strata seen to the south and north of the Clyde, and which has recently been established in still fuller detail in the "Geology of the Glasgow District."

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No. XV.—Notes on the Geological Survey Memoir. "The Geology of the Glasgow District." By James Neilson.

[Read 14th December, 1911.]

1. The Hurlet Datum Line.
2. The Thorntonhall Limestones.
3. The Garngad Cement Stone.

Introductory.

During the late summer the Geological Survey issued a map of the Glasgow district which will prove a boon not only to the members of this Society, but also to the increasing number of those who, although not members, still take an interest in geology as a branch of liberal education.

The present map differs from its predecessors in that it is colour-printed, and the printing and general details are brought out more clearly than was possible in the hand-coloured maps. This fact has been taken advantage of to add an enormous amount of detail, which is often of such a minute character that after study one feels inclined to wish that he were gifted with microscopic eyes or that the map had been drawn to a larger scale.

Not the least of its benefits is the low price at which it is sold (2s. on paper, and 3s. on cloth), the price of the previous maps having lately become prohibitive (19s. 3d. on paper).

It will be observed that the long way of the map is from north to south. This has doubtless been adopted for good and sufficient reasons, if we only knew them; but I, at least, would have preferred that the long way should have been east and west, with Glasgow in the centre.

The map is accompanied by an extensive memoir of the geology of the district, and the more one reads of it the more one is impressed with the extraordinary amount of information compressed between its covers and the enormous amount of good hard work required to collect, arrange, and classify all that information.

I know of no other class of writing in which so much good work is compressed into so little space and sold at such a

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low price, certainly not the cheap novels which are so popular nowadays; but why it should be issued in such trashy paper covers is one of these things no fellow can understand.

By none more than by the members of our own Society will these publications be welcomed, nor will any benefit by them more.

The work of a Society like ours, being carried on in their leisure hours by men engaged in other businesses, cannot fail to be fragmentary, and the advantage of a work like this is that, besides the new information, our work is linked up together into a sort of symmetrical history, which makes it more understandable to ourselves and others. We cannot but feel gratified at the prominent place awarded to the work of our Society in this memoir, and acknowledge with pleasure the handsome and generous manner in which this work has been recognised.

It would, however, be too much to expect that this memoir was the last word to be said on the subject. There are still some "missing links" to the chain, and it may be that some of the other links are not sound and require to be repaired or even replaced; and, if it can be shown that this is the case, I feel sure the authors will welcome the information and readily make the necessary changes.

I desire to-night to draw your attention to three points in which I differ from the Survey.

1. The Hurlet Datum Line.

Overlying the thick series of volcanic deposits which are referred to Calciferous Sandstone age are two different series of beds.

One of these is of deltaic origin, consisting of a great series of sandstones and conglomerates, of which Craigmaddie Moor is an example. These strata, which appear to be local only, and attain a thickness of about 600 feet, are not represented elsewhere.

Contemporaneous with these is a series of shales and limestones of undoubted marine origin. Sometimes, and for comparatively short periods, the land appears to have risen, and the delta (or at least fresh water) would cover the whole

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of our area, and even land would appear, as evidenced by thin coal seams; but on the whole there appears to have been a very gradual subsidence, and latterly the delta was driven backwards out of our area, and the whole covered by the sea.

This period is known as the Hurlet Limestone, and is now used by the Survey as the dividing line between the Calciferous Sandstone Series and the Lower Limestone Series.

It was not always so, as in sheet 23, p. 24, dated 1873, the Survey admit some 27 fathoms of strata, including six limestones and a coal, lower than the Main Limestone, as belonging to the Lower Limestone Series; but in their more recent publications this has been departed from.

In the west this has always been recognised since the time of Mr. John Craig's paper "On the Geology of the Lower Ward of Lanarkshire" (1839)[1] and Dr. Rankine's "Geology of the Parish of Carluke";[2] while in the first paper printed by this Society "On the Geology of the Campsie District" (1860), by Mr. John Young, Mr. Young gives the Craigenglen beds, the Balglass Burn beds, the Millburn beds, and the Balgrochan beds as all under the Hurlet Series, and also gives the journal of a bore 33 fathoms deep containing limestone, coal, and ironstone, with their usual accompaniments of shale, fireclay, fakes, &c., beneath these again.

The lowest persistent limestone of Lanarkshire and Ayrshire goes by the name of the Main Limestone, and has long been regarded as the equivalent of the Hurlet, but recent researches by the Survey have rendered this doubtful, and I would like a definite statement of what the Main Limestone of Lanarkshire and Ayrshire, and also the limestone of Corrie, Arran, really are.[3]

[1] Prize Essays of the Highland and Agricultural Society, vol vi.

[2] *Ib.*, vol. viii. About eighty years ago the above Society resolved to prepare Geological Maps and Memoirs of the whole of Scotland, and offered premiums of £50 for a county or a coalfield and £25 for a parish. In this way they must have spent about £1000 in premiums alone, and many good geological papers are found among these essays. The institution of the Geological Survey put an end to these papers. The Society's library contains eight volumes of these essays.

[3] The answer given to this question is that the Main Limestone is the equivalent of the Blackbyre. In that case it seems to me that the old name "Main Limestone" should be retained and the name "Blackbyre" dropped.

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While they are at it, I would like if they would also explain the relation of the Blackbyre Limestone to the Shelly Limestone of Rankine, also where the *Productus giganteus* limestone and the *Productus punctatus* beds come in.

Now, leaving aside in the meantime the deltaic or estuarine beds (Craigmaddie), it will be observed that, while the Survey list includes one plant of Calciferous Sandstone type associated with several belonging to the limestone group, the type of all the other strata, together with their contained fossils, is admittedly the same as the Hurlet Limestone and the overlying strata ("Geology of the Glasgow District," p. 84), yet the Hurlet and the beds overlying it are assigned to the Carboniferous Limestone Series, and those below the Hurlet to the Calciferous Sandstone. This does not seem to me to be a scientific division, and I can hardly think it would ever have been made from the evidence now before us; only, it has grown up, and the Survey have not broken away from the old tradition.[4]

The great thickness of the volcanic rocks of the Clyde plateau is well known. The Survey consider 2000 to 3000 feet not an excessive estimate (p. 98), but I am afraid Glasgow geologists are not sufficiently impressed with the enormous time occupied in the deposition of these rocks.

Some idea of this time may be had by comparing our strata with those in the neighbourhood of Edinburgh. According to the late Mr. Goodchild (*Transactions*, Edinburgh Geological Society, vol. viii.), there are underlying the Lower Limestone Series the

Oil Shale Series to the Burdiehouse Limestone at Broxburn and West Calder,	2400	feet.
Strata between the Burdiehouse Limestone and the Pumpherston shale,	800	,,
Sandstones and shales of Hailes and Redhall,	500	,,
Wardie shales in Craiglockhart cutting,	480	,,
Granton sandstone,	850	,,
	5030	feet.

[4] Since the above was in print I have been informed that in adopting the Hurlet Limestone as the base of the Carboniferous Limestone Series, the Geological Survey regards it as an arbitrary boundary, because marine limestones and marine shells occur below that horizon.

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Then come the Upper Ballagan beds or Abbey Hill shales.

As we have very few representatives of these beds in our district, it will be seen that our volcanic rocks represent a period equal to some 4000 or more feet of strata.

During this period we have a great palæontological break, many species disappearing at certain points and new species appearing at higher horizons, so that the fossils of the Calciferous Sandstone Series of Midlothian, Fife, the Solway, and Eskdale are very much different from those of the Lower Limestone Series, and my suggestion is that we draw the dividing line between the Calciferous Sandstone and the Lower Limestone Series at this great break in the fauna.

Where the break comes in we cannot say in our district; it is somewhere in the volcanic series, but until it can be localised my suggestion is that we might for convenience consider the whole of the volcanic rocks as Calciferous and all the overlying rocks as of Lower Limestone age.

The Hurlet Limestone might still continue a main datum line, and measurements made upward or downward from it.

2. The Thorntonhall Limestones.

Thirty-nine years ago, at the December meeting (1872) of this Society, I read my first geological paper, "On Some Sections of Carboniferous Limestone near Busby" (*Transactions*, vol. iv., p. 282). In that paper, after describing the strata, I drew attention to a bed of shale overlying the highest of these limestones, characterised by a very peculiar and distinctive suite of fossils, which I claimed to be an extension of a similar bed described by Mr. John Young, from the South Hill of Campsie, as overlying a limestone "supposed to be identical with the 'Hosie' Limestone,"[5] the fossils in both beds being remarkably alike.

At the close of the meeting (as reported in the *Glasgow Herald*) "Mr. Young expressed his concurrence in what Mr.

[5] Whatever it may have been originally, the term "Hosie" must now be considered to apply to a group of limestones near the top of the Lower Limestone Series rather than to a single bed. This particular bed has been dubbed the Blackhall by the *Survey*.

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Neilson had stated, as to the bed at Busby being the equivalent of that near Campsie to which he had referred. Local causes would account for any differences observable between them, or in the strata with which they were immediately associated."

These conclusions were also concurred in by the other members of our Society, including Mr. James Armstrong, whose adhesion is to be found in his "Catalogue of the Western Scottish Fossils," 1876 (p. 70), where, after describing this bed on the South Hill of Campsie and its contained fossils, he adds, "Strata on the same horizon are exposed between East Kilbride and Busby."

His remarks on the fossils of this section are equally applicable to the sections at Thorntonhall. He says, "The shale in question contains a large number of rare and beautiful fossils, some of which, as casts, are coated with the sulphide of iron, which gives them a fine metallic lustre." He then gives a list of fifteen of the more typical fossils, and every one of these has been found at Thorntonhall.

Dr. Young again refers to the subject in his paper on Carboniferous Ostracods.[6] Referring to the genus, he says, "*Polycope*.—This genus is represented by three species, two found in Western Scottish beds. These have been obtained from shales and small ironstone nodules found on the horizon of the Hosie Limestone in the Lower Limestone Series at Campsie, Carluke, and Busby."

These conclusions have never been called in question till early in the present year, when Mr. R. G. Carruthers read a paper to this Society, in which he maintained that the lower limestone of Thornton was the Blackbyre Limestone, and the Upper Limestone—which I had identified with the Hosie—was in reality the Hurlet, and this has been repeated in the Survey memoir of the Glasgow district.

I little thought when I read my paper that I would celebrate its fortieth birthday by standing before you in its defence. It is noteworthy, however, that Mr. Carruthers' conclusions have not been arrived at on fossil evidence. He appears to have overlooked my paper, for, had he consulted it, I can hardly

[7] *Transactions*, vol. ix., p. 301, 1891.

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think he would have come to his present conclusions; for, if fossils prove anything, the identity of these two beds has, in my opinion, been proved up to the hilt.

It has, however, become necessary to revise the evidence on which this identification was made. Dr. Young's paper "On the Geology of the Campsie District" has gone through three editions, and I propose to quote from the second edition, because this (as well as the other papers I will refer to) contains the old names, and so can be compared with my paper. The third edition contains the new names. The lists are taken from the Campsie Memoir.

In comparing the two lists, we will first eliminate the following species, which have a wide distribution:—

1. *Productus longispinus.*
2. *Spirifera glabra* (very abundant here).
3. *Spirifera lineata.*
4. *Leda attenuata.*
5. *Nucula gibbosa.*
6. *Bellerophon decussatus.*
7. *Bellerophon striatus.*
8. *Bellerophon Urei.*
9. *Orthoceras undatum.*
10. *Orthoceras attenuatum.*

All of which, with the exception of *Spirifera lineata*, are also got at Thorntonhall.

Only one of these species, viz., *Bellerophon Urei*, is recorded as from the shale above the Main Limestone, Campsie. About one-half are recorded from Corrieburn, but the horizon is not given.

There now remains a peculiar group of fossils which make their first appearance in our district in this bed, and never (taken as a group) are found in any other bed.

The next list is that of fossils which are not recorded from any other locality in the Campsie district; those prefixed by an asterisk are, so far as known, confined to this bed.

For comparison are shown, in parallel columns, fossils occurring in beds over the Hosie Limestone in other localities.

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CAMPSIE.	Thornton.	Hunter, Carluke, & Sheet 23.	Sheet 31.
*1. *Trigonocarpon* (small distinct species), -	×		
2. Small stems showing structure, - -	×		
*3. *Cythere* (*Polycope*) *Youngiana*, - -	×		*sp.*
4. *Dithyrocaris testudinens*, - - -	×		
*5. *Chonetes Hardrensis*, - - - -		×	×
Small figured variety Dav., - -	×		
6. *Leda longirostris* (*brevirostris*), - -	×	×	×
7. *Nucula luciniformis*, - - - -	×	×	
8. *Dentalium priscum*, - - - -	×	×	*ingens.*
9. ,, *inornatum*, - - - -	×	×	
10. *Euomphalus carbonarius*, - - -	×	×	×
*11. *Pleurotomaria conica*, - - - -		×	
Var. *decussata*, - - - -	×		
*12. *Bellerophon Oldhami*, - - - -	×	×	×
*13. *Goniatites Gilbertsoni*, - - - -	×	×	*some species.*
*14. ,, *Looneyi*, - - - -	×	×	
15. ,, *micronotus*, - - - -	×	×	
16. ,, *striatus*, - - - -		×	
17. ,, *vesica*, - - - - -			
18. *Nautilus biangulatus*, - - - -	×		
19. ,, *subsulcatus*, - - - -	×	×	
20. *Orthoceras cinctum*, - - - -	×	×	
21. ,, *dentaloideum*, - - -			
22. ,, *Goldfusianium*, - - -	×		
23. ,, *Muensterianium*, - - -			
24. ,, *pygmeum*, - - - -			
25. *Rhizodopsis minor*, - - - -	×		
	20	14	

It will be noticed that, with the exception of five species of small Goniatites and Orthoceratites which are very difficult to identify, the lists are alike, while not one of the above species is recorded elsewhere from the Campsie district.

The following are also recorded from Craigenglen:—

26. *Spirifera Urei* (rare at Craigenglen), -	×	×	

In thousands over the Hosie Limestone in both localities.

27. *Nucula lineata*, - - - - -	×	×	
28. *Loxonema curvilinea*, - - - -	×		
29. *Cyrtoceras rogusum*, - - - -	×	×	

The following is recorded from Corrieburn:—

30. *Chonetes* var. *gibberula*, - - - -	×		
	25	17	

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But as Corrieburn contains a wide range of strata, it is probable that this is from the bed in question.

The remarkable thing is that not one of the above thirty species are recorded from the top of the main limestone of any locality in the Campsie district.

The species in first list numbered 4 to 10 inclusive also belong to this group, and it is noteworthy that only one, *Bellerophon Urei*, is recorded from the Main Limestone shales of Campsie.

The list of fossils from Thornton is very much longer, this being accounted for by the fact that the fossils from Campsie could, as a rule, only be got from pit sinkings, while Thornton was wrought as an open-cast quarry.

Fossils from Thornton not recorded from Hosie Limestone, Campsie—

	Carluke.	Sheet 31.
1. *Stenopora tumida*,		
2. *Palæchis cyclostoma*,	×	×
3. *Zaphrentis Phillipsi*,	×	*Sp.*
4. *Cyathophyllum*,		
5. *Archæocidaris Urei*,	×	*Sp.*
6. *Actinocrinus*,		*Sp.*
7. *Serpulites carbonarius*,		
8. ,, *membranaceus*,		
9. *Griffithides*.		×
10. *Chonetes polita*,	×	
11. *Leda intermedia*,	×	×
12. *Euomphalus tuberculatus*,		
13. *Loxonema scalaroidea*,		
14. *Macrocheilus acutus*,		
15. ,, *fusiformis*,		
16. ,, *imbricatus*,	×	×
17. *Platyceras neratiodes*,		
18. *Pleurotomaria*,		
19. *Cyrtoceras unguis*,		
20. *Goniatites diadema*,		
21. ,, *excavatus*,		
22. ,, *micronotus*,	×	
23. ,, *mutabilus*,		
24. *Nautilus globatus*,		
25. *Orthoceras ovale*,	×	
26. ,, *pyramidale*,		
	8	4

Only two of the above *Serpulites carbonarius* and *Griffithides, sp.*, are recorded from the Main Limestone of Campsie.

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	Campsie.	Thornton.	Carluke.	Main Limestone, Campsie.
Abstract.				
Fossils generally distributed through Lower Carboniferous, - - - -	10	9	7	1
Peculiar Group from Campsie list, - - -	30	25	17	
Totals, - - -	40	34	24	1
Peculiar Group from Thornton and later lists,		26	8	2
	40	60	32	3

Dr. Hunter's (Selkirk), of Braidwood, Carluke, list of fossils from Bed No. 560, Hosie Limestone shale, Braidwood (p. 81), shows a resemblance to the Thornton bed, and contains its principal distinctive fossils, including *Bellerophon Oldhami* and *Goniatites Gilbertsoni*.

He also gives a short list (beds 590-2) from shales over the main limestone, of which *Archæocidaris Urei* is the only one got at Thornton. He also gives a very long list from the main limestone, which has no affinity whatever to the Hosie bed.

In the Geological Survey's Explanation of Sheet 23 (preface dated November, 1873) a long list of fossils is given (p. 61) from "main limestone and beds above." At localities 3 and 6 the fossils are from a shale about 15 feet above the main limestone. These are our Thornton localities, and this shale is the one now in question. Eliminating these, the others have no resemblance whatever, while in shale overlying the second Calmy limestone we have *Bellerophon Oldhami*, and in shale above Hosie Limestone, Carluke (p. 66), we have some of our most characteristic species.

In the Survey Sheet 31 (p. 68) we have a list of fossils from shale and nodules above Hosie Limestone which contains several of our characteristic fossils, viz., *Palæchis cyclostoma*, *Polycope*, sp., *Leda brevirostis*, *Bellerophon Oldhami*, and some species of *Goniatites*.

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The collection of the late Mr. Linn of Livingstone, however, contained a great many more, so that I could tell him the position of these beds before the Survey memoir was issued. This collection is now, I think, in the Royal Scottish Museum, and can probably be referred to, and Dr. Lee has also given me a list of fossils collected by Mr. James Bennie.

The localities would probably be Nos. 30 to 34 in the Geological Survey's sheet 31, in the Blackburn district.

I also claimed in a previous paper that this bed occurred in the neighbourhood of Dunfermline, and the Survey memoir of Central and Western Fife seems to bear this out, the localities being Nos. 20 to 23, although the number of species given is too small to say definitely.

In looking over Survey Sheets Nos. 23 and 31 one is struck by the paucity of Dimyarian Lamellibranchs in shales overlying the Hurlet Limestone, these being all but absent in the majority of localities, while they are the strong point in the shales of the Hosie Limestone.

I claim therefore—

1. That these two beds are identical.
2. That this peculiar group of fossils made its first appearance in the West of Scotland in this bed.
3. That this group, taken as a whole, is confined to this bed, and never again puts in an appearance.[7]

[7] At the February, 1912, meeting of the Geological Society of Glasgow Mr. Macnair adversely criticised the above conclusions, and in the *Glasgow Herald* of 20th February he is reported to have said—

(1) That the characteristic fauna discovered by Dr. Young in the shales above the Blackhall Limestone of the South Hill of Campsie also occurs above the Hurlet Limestone of Thorntonhall; and

(2) In the Calderwood Limestone of East Kilbride;

(3) But it seems likely that this fauna is limited to the Lower Limestone Series, and does not pass into the Upper Limestones.

(4) That the aforementioned fauna is associated with species which range from the top to the bottom of the Limestone Series.

To which my reply is—

(1) The bed referred to at Thorntonhall is the bed we have been discussing. His is a very cavalier way of replying. He used no arguments and replied to none, but simply stated in an *ex cathedra* style, such as a pope might use, that this was so. Meantime, I challenge him to produce a list of fossils from any unquestioned Hurlet bed at all like the present. I have searched and failed, and I await the result of his researches.

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Comparison of Strata.

We will next consider the evidence to be derived from a comparison of the strata at the two localities, and for this purpose we take the section (given on p. 23 of the Survey Memoir) of the old pit on the top of the South Brae and north of Newlands (Campsie), and compare it with the section at Thornton old quarry, as shown in the accompanying diagram, in which I have placed the top of the two Upper Limestones opposite each other.

The explanations are drawn from Mr. Young's memoir, and every word he says regarding the strata between the limestones applies equally well to the beds at Thornton. The topmost black shale is the one we have hitherto been speaking of, and it will be noticed that every important bed represented in the Campsie section has its equivalent in its proper relative position at Thornton. It is also worthy of note that the whole of the strata are fresh water, whereas the Hurlet Limestone is, I think, almost invariably underlaid by a marine shale.

The first notable bed under the limestone is a bituminous or oil shale, in which occur numerous fish remains, consisting of scattered scales, bones, spines, and teeth, mostly of Ganoids.

(2) I know the Calderwood fauna very well. I knew it when the beds were being worked open-cast, and when one had a much better chance of seeing them than now, and I know of no such bed, nor of any list which would warrant Mr. Macnair's statement, and must again call upon him to produce his list.

(3) Mr. Macnair is very unfortunate in his statement, as of the thirty species given in my list as characteristic of the Campsie bed, no less than seventeen continued into the Upper Limestones, and the curious thing is that a number of them are supplied by Mr. Macnair himself from Thornliebank. (*Transactions*, vol. xii. p. 375.)

(4) Admitted. I have referred to this bed in two previous papers ("Calderwood Limestone and Cement Stone," *Transactions*, vol. x., p. 74; History of Geological Society of Glasgow, p. 160), but my claim was that, as a group, these fossils made their first and last appearance in Carboniferous times in this bed, and I submit that the group is a stronger argument than the single fossil, which is liable to be upset at any moment. Thus, if I had been asked some years ago to name the two most characteristic fossils confined to this bed, I would have replied, *Polycope Youngiana* and *Goniatites* (*Dimorphoceras*) *Gilbertsoni*, but this latter has been found by Mr. Tait in the Calciferous Sandstone of Fife, and is also recorded from the Upper Red Barren Measures of Scotland,[8] so it may be found in our district any day.

[8] J. Smith of Dalry and C. T. Clough, M.A. *See* Summary of Progress of the Geological Society for 1907, p. 127.

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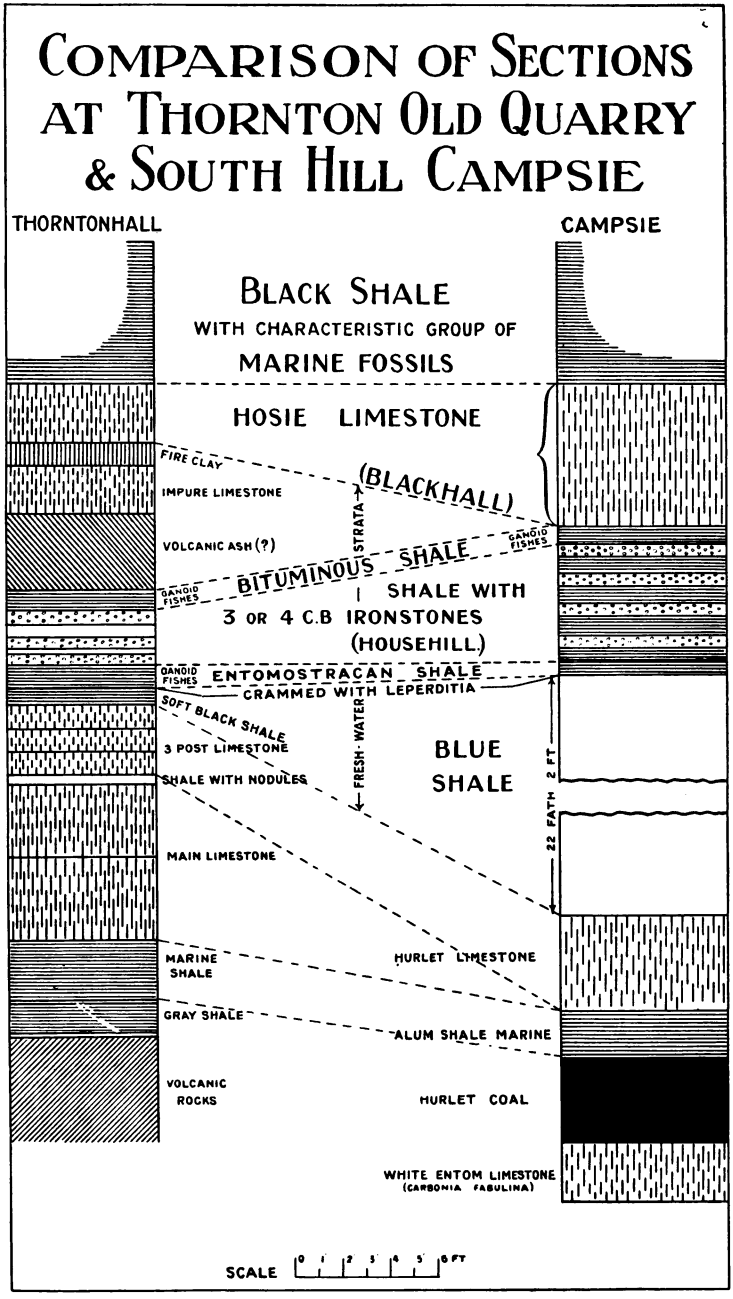

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This is followed by three or four ironstone bands, with shale beds between them (Memoir, p. 22), and which the Survey in the Campsie section identify with the Househill.

Underlying this is an Entomostracan shale crammed with, and in some parts almost made up of, cases of *Leperditia Scotoburdigalensis*, Hib. This is certainly not the same as the White Entomostracan Limestone which underlies the Hurlet coal in the Campsie district, as this is a shale, and the Entomostraca with which the latter is charged are *Carbonia fabulina* (3rd Edition, p. 40), and both beds are found in Campsie.

Mr. Young also states, "I have not been able to discover evidence of the existence of any of these (Entomostracan) limestones out of the Campsie district in the same geological horizons, and it is possible that they are merely local deposits soon thinning out."

In my paper I am made to say that "this bed resembles to a certain extent some of the Entomostracan shales of the West Calder coalfield." Now, I never wrote these words, never saw them till I saw them in print, but I am inclined to attribute them to Mr. Young, as a similar remark is made in his paper, and to consider it as a recognition of the Thornton bed as an equivalent to the one at Campsie.

Next in order comes a blue shale 22 fathoms 2 feet thick at Campsie, which has dwindled down to a soft black shale about 1 foot thick at Thornton. Such enormous variations are not unknown, but the fact remains that the Thornton shale, in all but thickness, is a replica of the Campsie bed.

The Lower Limestone is about 4 feet thick at Campsie, against 10 feet at Thornton, and it may well be that part of the latter is contemporary with the thick shale bed at Campsie.

The shale underlying the limestone in both cases is of marine origin, containing many fossils not at all distinctive. I am under the impression that the Hurlet Limestone is always underlaid by a marine shale. The shale underlying the Upper Limestone at Thornton is fresh-water.

The absence of the Hurlet coal at Thornton does not affect the argument either way, unless it were sought to prove that neither of these limestones was the Hurlet. The coal is very inconstant; in some localities being very thin, and only of use in burning the limestone.

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The grey shale at Thornton is a re-wash from the volcanic rocks, on which the whole section reposes, and which comes to the surface within about 100 yards of the quarry.

I have already referred to the White Entomostracan Limestone.

That the Lower Limestone at Campsie is the Hurlet there is no doubt, as it has the typical accompaniments, limestone, alum shale, and coal, which were long wrought by the Hurlet and Campsie Alum Company."

3. The Garngad and Glenboig Cement Limestones.

In the year 1875 I read to this Society a paper entitled "Geological Notes on the Cuttings in the City of Glasgow Union Railway between Bellgrove and Springburn" (*Transactions*, vol. v., p. 222), in which I described the various sections exposed during the progress of the work, also giving a list of their fossil contents. This paper has become a rather important one, not, however, from any special merit it possessed—it is simply a plain record of the sections seen and of their contents, and ought to be an encouragement to our young members, any of whom could have done it equally well, and some a great deal better. In the Survey Memoir it is spoken of as "the valuable paper," its value being due to the fact that many of the sections have been covered up, and it remains the only authority on many of the points stated in it.

Some of these rocks between Blochairn Road and Garngad Road, belonging to the Millstone Grit Series, consist of thin-bedded sandstones and shales, and the peculiar thing is that the sandstones are charged with marine fossils. This section is followed by another, in which we find—

Sandstone, thin-bedded, - - - -	1 ft. 9 in.
Sandstone, with casts of shells, - -	0 ,, 9 ,,
Kingle, - - - - - - - -	2 ,, 6 ,,
Shale, calcareous (fossiliferous), - -	1 ,, 0 ,,
Cement, - - - - - - - -	1 ,, 1 ,,
Shale (not cut through) exposed about, -	6 ,, 0 ,,

At the time my paper was written the Garngad Road Quarry, about 180 yards east of the station, had not been opened, but

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the Survey consider that the lowest coal exposed there is about 40 feet above the cement (p. 57), and the sandstones contain plant remains of Lower Carboniferous facies.

The Survey (p. 54) describe "a thin bed of marine limestone" known locally as the "Cement Stone" or "Roman Cement," which is persistent for a long distance several miles east of Glasgow. They, however, state, "Within the city it has been recognised in a small exposure at Garngad Road Station."

They also say, "From the character and fossil contents of this bed it may be inferred that it represents the 'Cement Stone' described in an earlier paragraph as occurring 30 to 40 feet above the base of the Millstone Grit" (p. 57).

It is again referred to in page 90.

I am not, however, prepared to recognise the identity of the two beds, my reason being the great difference in the fossil contents.

In a shale immediately above the cement at Greenfoot Quarry, on the farm of Gain, near Glenboig Station, and elsewhere the Survey found what is probably the most remarkable group of fossils ever recorded in Scotland. The Lamellibranchs and Gasteropods have been described by Dr. Hind.[9]

Dr. Hind says it "contains a number of species hitherto unrecorded from Europe, so far as my knowledge goes; but, on the other hand, it exhibits a remarkably close affinity to the Lamellibranch fauna described by Meek from the coal measures of Nebraska, Illinois, and other American States.

In all twenty-six species of Lamellibranchs are recorded from Scotland, of which eleven are also found in Nebraska, while five are new, but there is only one species common to Nebraska, Scotland, and England.

Dr. G. W. Lee, palæontologist to the Geological Survey, has favoured me with the following list of Brachiopods:—

Orbiculoidea (*Discina*) *nitida*.
Lingula mytiloides.
Lingula squamiformis.
Derbya, sp.
Productus, *cf. semireticulatus*.

[9] "On the Lamellibranch and Gasteropod Fauna found in the Millstone Grit of Scotland." *Trans. Roy. Soc. Edin.*, 1908, Part II., p. 331.

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TABLE SHOWING THE LAMELLIBRANCH FAUNA OF THE COAL MEASURES OF NEBRASKA, AND THE OCCURRENCE OF THE SAME SPECIES IN EUROPE.

	Nebraska.	Scotland.	Congleton Edge.	Hazel Hill.	Base of Bristol Coal Measures.	Russia.
Limatulina alternata, M'Coy, sp.,		×				
Palæolima retifera, Shumard,	×				×	
Entolium aviculatum, Swallow, sp.,	×					× ‡
Nucula Beyrichi, V. Schaur. ?	×					
,, *gibbosa*, Flem.,		×				
,, *ventricosa*, Hall,	×					
Yoldia subscitula, M. and H ,	×					
Nuculana lævistriata, M. and W., sp.,	×	×				
,, *attenuata*, Flem., sp.,		×				
Ctenodonta lævirostris, Portlock sp.,		×				
Grammatodon tenuistriata, M. and W., sp.,	×	×			×	× *
Protoschizodus curtus, M. and W., sp.,	×	×				
Schizodus Wheeleri, Swallow, sp.,	×	×				× †‡
Avicula longa, Geinitz,	×					
,, *? sulcata*, Geinitz,	×					
Pseudomonotis radialis, Phill., sp.,	×					× ‡
Myalina Swallovi, M'Chesney,	×					
,, *subquadrata*, Shumard,	×					
,, *perattenuata*, M. and W.,	×					
,, *Verneuilii*, M'Coy,		×				
Aviculopecten occidentalis, Shumard, sp.,	×					
,, *neglectus*, Geinitz, sp.,	×	×				
,, *carboniferus*, Stevens, sp.,	×		×	×		× ‡
,, *coxanus*, M. and W.,	×					
,, *obliquus*, sp. nov.,		×				
,, *regularis*, sp. nov.,		×				

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Pterinopecten papyraceus, Sow., sp.,		×			×	
,, *Whitei*, Meek, sp.,	×	×				
Posidoniella lævis, Brown, sp.,		×	×		×	
Aviculopinna americanna, Meek,	×					
Pinna peracuta, Shumard,	×					
Modiola ? subelliptica, Meek,	×					
Pleurophorus oblongus, Meek,	×					× ‡
Sanguinolites occidentalis, M. and H., sp.,	×	×				
Edmondia reflexa, Meek,	×	×				
,, *glabra*, Meek,	×					
,, *nebrascensis*, Geinitz, sp.,	×	×				× †‡
,, *subtruncata*, Meek,	×					
,, *aspinwallensis*, Meek,	×					
,, *Lyellii*, Hind,		×				
,, *sulcata*, Phill., sp.,		×				
Allorisma reflexa, Meek,	×	×				
,, *Geinitzi*, Meek,	×					
,, *subelegans*, Meek,	×					
,, *granosa*, Shumard, sp.,	×					
,, *subcuneata*, M. and H.,	×					× ‡
Tellinomorpha Hindii, Bolton,		×			×	
Solenomorpha cylindrica, sp. nov.,		×				
Solenomya brevis, sp. nov.,		×				
,, *cylindrica*, sp. nov.,		×				
Prothyris elegans, Meek,	×	×				
Solenopsis solenoides, Geinitz, sp.,	×					
Total, 52	37	26	2	1	5	8

* Tschernyschew, "Obercarbonischen Brachiopoden d. Ural u. d. Timan," *Mém. Com. Géol. Russie*, 1902.

† Stuckenberg, "Die Fauna der obercarbon. Suite des Wolgadurbruches bei Samara," *Mém. Com. Géol. Russie*, 1905, Livr. 23.

‡ Jakowlew, "Die Fauna der oberen Abtheilung der Palæozoischen Ablagerungen im Donetz Bassin: Die Lamellibranchiaten," *Mém. Com. Géol. Russie*, 1903.

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These have not the slightest affinity to the shells found in connection with the cement at Garngad, but resemble those found in the quarry about 100 feet higher in the section, and represent the last stage of exhaustion before extinction.

Garngad.

The cement shale at Garngad also contains a characteristic group of fossils, which, while not so startling yet is very striking in its own way.

The prevailing group is that of the Brachiopods, which form two-thirds or three-fourths of the entire fossils; nineteen species are recorded, the commonest being *Orthis resupinata*, followed by some seven species of *Productus*, also *Spirifera*, *Athyris*, *Streptorhynchus*, *Lingula*, and *Discina*, some of these being very noteworthy, *e.g.*, *Productus carbonarius*, de Kon., its only British locality, although it is found in a similar horizon in Belgium. *P. sinuatus*, *P. muricatus*, *Discina Craigii*, *Streptorhynchus var. robusta* first figured in our *Transactions* (vol. ii., p. 76), found by Mr. Thomson, Tirfergus Glen, Campbeltown. It was afterwards figured by Davidson under the name of *S. cylindrica*.

The specimens from Garngad Road were, however, casts showing the muscular impressions and dental plates, and a writer in "Paleontologica Indica" (Waagen, 50, p. 606), suggested that this was really a *Meekella*. It has since been described as *Meekella Neilsoni*, Thomas.[10] Mr. Thomson's species now rejoices in the name of *Schwellwienella rotundata*, Thomas.[11]

Revision of the Lamellibranchs has played sad havoc with the old names, and it may be as well to give the list entire as revised.

**Limatulina alternata*—rare in nodules.
Aviculopecten dissimilis—common.
Aviculopecten interstitialis—rare.
Aviculopecten Murchisoni—rare.

[10] British Orthotetidæ. "Memoirs of Geol. Survey of Great Britain," Vol. I., Pl. 2, p. 114; Pl. 13, figs. 3 and 4.

[11] *Ib.*, p. 123, Pl. 13, pp. 14-15.

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Allorisma sulcata. Flem. (Plate xlviii., Fig. 7)—common.
Cardiomorpha limosa (Plate xxi., Fig. 8)—rare.
Cypricardella rectangularis.
Edmondia Josepha—common.
Edmondia traversa. Hind (Plate xxxii., Fig. 13)—common.
Nucula gibbosa—common.
**Nuculana attenuata*—common.
Nuculana Sharmani (Plate xv., Figs. 17 and 18)—common.
Nuculana brevirostris—rare.
Myalina Flemingi, M'Coy (Plate iv., Fig. 10)—rare.
**Myalina Verneuili*, M'Coy (Plate iii., Fig. 6, and Plate iv., Fig. 4)—common.
Protoschizodus axiniformis (Plate xvii., Fig. 18)—common.
Tellinomorpha cuneiformis, de Kon.—rare.

It will therefore be observed that, of the twenty-six species recorded for the Survey, only three (marked with an asterisk) are found in Garngad, and not one of these is American. Seven of the above have been figured in Dr. Hind's monograph of Carboniferous Lamellibranchs, besides two Brachiopods by Davidson and Kitchen, and this is the only locality in the West of Scotland from which *Nuculana Sharmani* has been recorded. It was originally described for the Calciferous Sandstones of Midlothian.

With regard to the Gasteropoda, these are rare at Glenboig, but Dr. Hind figures some seven from generally defective specimens, but these can all be paralleled, or very nearly so, from Garngad, though we have been in the habit of giving them different names, and I place opposite his list the names given in my list.

Entalis Meekianium, Genitz.	*Dentalium inornatium*, McCoy.
Ptyhcomphalus Marcouianus, Genitz.	*Pleurotomaria striata*, Sow.
Bellerophon Marcouianus, Genitz.	*Bellerophon decussatus, var. striatus.*
Euphemus d'Orbignyi, Portl.	*Bellerophon Urei*, Flem.
Naticopsis brevispira.	*Macrocheilus imbricatus*, Sow, *and Naticopsis variata*, Phill.

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Note, these are great varieties of *Bellerophon Urei*. In the young stage it showed, as in Dr. Hind's figures, without a keel, but as it grew it developed a very strong keel. Sometimes, however, it grew to quite a large size without showing any keel.

Gasteropoda as a whole were quite common at Garngad.

Dr. Hind speaks of the Cephalopoda as represented by a single species, and apparently by a single fragmentary specimen, referred to *Glyphioceras Phillipsi*. Now, while Goniatites were rare at Garngad, *Nautilus nodiferus*, Armstrong (*Pleuronautilus dorso-cariniferus*), was common—commoner here than in any other locality I know, while *Nautilus quadratus* (*Stoboceras sulcatus*) was not to call rare.

It will thus be seen that the difference between the two groups of fossils is very great, and these point to great differences in the conditions under which they were deposited.

The Garngad fauna lived under truly marine conditions, yet so near land as to make it unsuitable for Corals and almost so for Crinoids; still the abundance of Brachiopods shows that they were in the open sea. The other beds, as shown especially by their Lamellibranchs, were deposited in more or less brackish water, in which the more marine types could not thrive—possibly lagoons or other enclosed areas; and it is difficult to imagine conditions shutting off these two localities within 8 miles of each other, so that two such different types of fossils existed, and not one American species could find its way to Garngad, although they must have travelled some 4000 miles and passed over this very ground on their way to (or from) Greenfoot; for, although the genus *Meekella* is American, and has hitherto been believed to be confined to the Carboniferous rocks of America, Eastern Europe, and China, still the species found in this locality is neither, being like the one after whom it is named, wholly and solely Scottish.

The sections shown in Dr. Hind's memoir show that the fossils came from more than one horizon and probably more than one cement, and it seems to me that another cement yet requires to be added, viz., that of Garngad.

Another point may be mentioned. Dr. Hind states (p. 334), "I think that all the Lamellibranchs were obtained from beds

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containing a Lower Carboniferous flora, and just below the point where the upper and lower flora meet."

Now the Survey give a list of plants of Lower Carboniferous facies from Garngad Quarry in a position 73 feet above the cement, while the top of the quarry is 58 to 68 feet above that again (total 131 to 141 feet), so the Garngad cement at least can hardly be described as "just below the point where the upper and lower floras meet."

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PROCEEDINGS OF THE GEOLOGICAL SOCIETY OF GLASGOW.

SESSION 1911-1912.

(Fifty-fourth Session.)

REPORT OF THE COUNCIL FOR 1910-1911.

(Submitted 9th November, 1911.)

In submitting their Annual Report, the Council again have to regret that there has been a considerable falling off in the membership during the past session. The number of members on the roll of the Society at the commencement of last year, 1910-1911, appears to have been 165. During the session 5 new Ordinary Members were enrolled, and there were 15 resignations, besides one member being removed by death. This left the number at the end of the session at 154. The resignations seem somewhat heavy, but several of these had been in contemplation for some time, and were only intimated during the session just closed. The younger members of the Society may be reminded that during past years the ranks of the Society have been mainly recruited by a number of the members who took a particular interest in securing new and desirable persons for election as members; they are therefore urgently requested to induce as many of their friends as would be likely to take an interest in the Society to join its ranks.

The Finances will be reported upon by the Hon. Treasurer, Mr. E. Hall Wight, and the Library by the Librarian, Mr. William Sinclair.

During the session eight meetings were held, which were well attended. A number of important papers were contributed at these meetings, including the following:—By Mr. Wm. Sinclair, on "The Relationship between the Raised Beach and the Boulder Clay of the West Coast of Cantyre"; by Professor Gregory, "Further Notes on the Scandinavian Overthrust"; and "The Recent Glasgow Earthquake," the latter delivered as his Presidential address; by Mr. R. G. Carruthers on "The Geology of East Kilbride"; by Mr. Peter Macnair on "The Recent Floods in Perthshire—their Geological Lessons"; by Mr. John Smith on "The Carboniferous Rocks of the Isle of Man"; and by Mr. R. W. Dron on "Bores at Manor Powis Coalfield."

A large number of specimens of rocks, minerals, and fossils were exhibited at the various meetings; also Mr. J. W. Reoch exhibited by lantern a large and interesting collection of photographs of the Tertiary Igneous Rocks of Skye, with descriptive geological notes.

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During the summer months fifteen excursions took place, some of which were well attended, but others not so well as might have been desired. These and their conductors were as follows:—

Kelvingrove Museum.—Mr. Peter Macnair.
New Luce, Wigtownshire.—Mr. John Smith.
Ballagan, Stirlingshire.—Mr. J. W. Reoch.
Aberfoyle, Perthshire.—Mr. Peter Macnair.
Arthur's Seat, Edinburgh.—Dr. B. N. Peach.
Luss, Loch Lomond.—Professor J. W. Gregory.
Cathkin Braes.—Mr. Robert Boyle.
Bishopbriggs.—Mr. George C. Watson.
Clydebank Waterworks and the Whangie.—Mr. N. Martin and Mr. Robert Boyle.
New Pit, near Prestwick.—Mr. D. S. Ferguson.
The Lang Craigs, Dumbarton.—Mr. G. W. Tyrrell and Mr. H. R. J. Conacher.
The Scottish Exhibition.—Mr. John Renwick.
Loch Doon and Ness Glen, Ayrshire.—Mr. F. Mort.

The only death which we have to record is that of Dr. James Lambie, of Kilwinning, who joined the Society in the year 1905.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH OCTOBER, 1911.

The first meeting of the fifty-fourth Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., F.G.S., *President*, in the chair.

The Minutes of the last meeting were read and adopted.

The Rev. A. Ritchie, M.A., 8 Queen Margaret Crescent, Hillhead, as proposed by Mr. Peter Macnair and Mr. J. W. Reoch, was elected as an Ordinary Member.

Professor GRENVILLE A. J. COLE, F.G.S., delivered an address entitled, "Ireland, the European Outpost." Professor Cole said there was no need to remind any one in Glasgow of the close links between Ireland and the history of the Western Highlands and the Isles of Scotland. Probably Columba himself, in his exile in Iona, noted the similarity between the rocks of Staffa and the cliffs that he had left behind him on the Antrim coast. The study of the structure of Ireland reveals many larger features which repeat themselves in Scotland, and which run on into the continent of Europe. Ireland was, in fact, clearly an outpost of Western Europe. In early days, however, the Irish area must have again and again lain upon the margin of a north-western continent, which was founded when the old gneissic rocks of the Outer Hebrides were lifted above the sea. This old floor to the country, so conspicuous in Scotland and Scandinavia, appears perhaps in the centre of Tyrone, but the Irish Western Highlands are for the most part formed of altered sedimentary rocks, quartzites, mica-schists, and occasional limestones, like those that are folded together to form the Central and Southern Grampians. These were

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reared into continental land before Cambrian times, and the first Silurian beds in Mayo and Galway lie unconformably upon their worn-down edges. The junction, representing the incursion of the great Silurian sea, is well seen on the hillsides south of Killary Harbour. The Silurian beds and their precursors were then alike folded in mountainous ridges and hollows, with a south-west and north-east trend, in early Devonian times, and these folds to this day control the surface features of a large part of Ireland. The Leinster Chain, with its Silurian foothills deeply notched by streams, and its core of granite, forming a long moorland, represents this folding on the south-east. North of it a hummocky Silurian axis runs on into that of the Scottish Southern Uplands, and the ridges of crystalline rock in the north-west of Ireland are prolongations of the similar folded masses in the Grampians. These are repeated again in the great axis of Scandinavia. The east and west folds that arose at the close of the Carboniferous times, and gave to Ireland the bold ridges of Old Red Sandstone in the south, similarly pass across England into Central Europe. The sea that gave Europe its marine Triassic, Jurassic, and Cretaceous strata hardly encroached on the Irish area, which still clung, as it were, to the old north-western continental land. However, in Eocene times the volcanic activity of Antrim and of the Inner Hebrides was a herald of the striking changes that gave birth to modern Europe. As the Pyrenees, Alps, and Carpathians arose the Atlantic spread over the western lands, and Ireland, for good or ill, became annexed to the growing continent on the east. Since then she has lost ground to the ocean, but has maintained her position on the continental shelf. The present Irish Channel, indeed, was determined by a post-glacial subsidence. The traditions of the Isles of the Blest, seen only from the west coast at sunset, may point to land actually visible when man first came into the country; but may we not say that Ireland to-day looks east, not west, and with her zeal in education and her renewed energy in industrial organisation, seeks to take her place as the outpost of that Europe which spread eastward from her old foundations?

Professor GREGORY expressed his appreciation of Professor Cole's address, as did also Mr. JAMES NEILSON.

Mr. JAMES STARK asked if in Ireland there were any evidences on the surface of great faults equivalent to the Highland Boundary and the Southern Uplands faults in Scotland, or if these had been covered by the more recent Carboniferous Limestones.

Mr. G. W. TYRRELL, in referring to the E.—W. dykes, due to the shrinkage during Eocene times, also drew attention to the E.—W. dykes in Ireland that were older than the Tertiary and have the same direction as the Hercynian folds, these dykes differing from the others in being broader and longer, and being composed of a different type of rock.

Professor COLE, in replying, stated that it was very difficult to say what is the age of the N.E.—S.W. faults. The boundary faults were, of course, due to folding. There is in Donegal a great fault, almost cutting Donegal right through, and that glen in which it occurs runs in the Caledonian direction. It is quite possible that

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that is the same slip that gave rise to these faults that appear in Scotland. He was obliged to Mr. Tyrrell for reminding us of these older E.—W. dykes, and expressed pleasure that new points had been raised by members.

On the motion of the Chairman, Professor Cole was heartily thanked for his address.

(Signed) J. W. GREGORY.

SOCIETY'S ROOMS, 207 BATH STREET, 9TH NOVEMBER, 1911.

The second meeting of the fifty-fourth Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., F.G.S., *President*, in the chair.

The Minutes of last meeting were read and adopted.

The Annual Report of the Council was read, and on the motion of Mr. E. W. Gemmell, seconded by Mr. James Steel, was unanimously adopted.

The Annual Reports of the Treasurer and the Librarian were also read, and on the motion of Mr. G. W. Tyrrell, seconded by Mr. Wm. M'Creath, unanimously adopted.

The following office-bearers were elected:—

President—Dr. John Horne, F.R.S., F.G.S., proposed by Professor J. W. Gregory and Mr. Peter Macnair.

Vice-President—Professor J. W. Gregory, D.Sc., F.R.S., F.G.S., proposed by Mr. John Renwick and Mr. William Sinclair.

Members of Council—Mr. Charles R. Cowie, proposed by Mr. Wm. Sinclair and Mr. John Renwick; Mr. Duncan Smith, proposed by Mr. Alex. M'Lean and Mr. J. W. Reoch; Mr. P. Arthur Leitch, proposed by Mr. J. W. Reoch and Miss A. T. Neilson; Mr. Andrew C. Keir, proposed by Mr. Peter Macnair and Mr. J. W. Reoch.

Hon. Secretaries—Mr. Peter Macnair, F.R.S.E., F.G.S., and Mr. J. W. Reoch, proposed by Mr. James Stark and Mr. James Steel.

Hon. Treasurer—Mr. E. Hall Wight, proposed by Mr. Jas. L. Begg and Mr. Wm. Lyle.

Hon. Librarian—Mr. William Sinclair, proposed by Mr. Arch. A. Young and Mr. E. Hall Wight.

On the motion of Mr. JAMES NEILSON, Mr. David Pearson and Mr. A. Macintyre were re-appointed as Auditors.

The following members were elected:—

As Ordinary Members—Dr. J. D. Falconer, F.R.S.E., Lecturer on Geography, the University, Glasgow, proposed by Professor J. W. Gregory and Mr. John Renwick; Mr. Andrew Barclay, F.E.I.S., Possilpark Public School, proposed by Mr. Peter Macnair and Mr. J. W. Reoch; Mr. B. K. N. Wyllie, M.A., Students' Settlement, 10 Possil Road, proposed by Mr. G. W. Tyrrell and Miss A. T. Neilson; Mr. Alexander Fleck, B.Sc., Dean Terrace, Stepps, proposed by Mr. G. W. Tyrrell and Miss A. T. Neilson; Mr. William R. Smellie, M.A., B.Sc., Mayfield Villa, Mossend, proposed by Mr. G. W. Tyrrell and Miss A. T. Neilson.

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As Associate Members—Mr. Alex. Scott, M.A., B.Sc., 137 St. Andrew's Road, Pollokshields, proposed by Mr. G. W. Tyrrell and Miss A. T. Neilson; Mr. Alex. Stevens, M.A., Students' Settlement, 10 Possil Road, proposed by Mr. G. W. Tyrrell and Miss A. T. Neilson; Miss Isabella Kelly, c/o Miss Mitchell, 8 Carfin Street, Crosshill, proposed by Mr. G. W. Tyrrell and Miss A. T. Neilson.

Mr. JOHN RENWICK gave notice that he would move at next meeting "That £15 of the Society's funds be granted for Library purposes."

Mr. JOHN SMITH exhibited and described a large and interesting series of lantern slides (from photographs taken by Mr. Robert Dunlop) in illustration of a paper read by him last Session on "The Carboniferous Rocks of the Isle of Man."

Mr. GEORGE C. WATSON showed photographic slides of the "Haystack," Scalpsie Bay, Bute, describing briefly the points of interest in connection with it, and suggesting that the origin of the conglomerate of which it is composed was terrestrial.

Mr. WILLIAM M'CREATH exhibited a glass model showing the strata of part of the Kilsyth coalfield, and read notes descriptive of it. This model showed in a very clear manner the disposition of the coal strata over a considerable area, and how they had been shifted from their original positions of deposition by folding and faulting.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., *Honorary Secretary*, exhibited specimens of the estuarine shale obtained from a section recently exposed near Rouken Glen. These well exemplified the interesting characteristics of this band of shale, which in a thickness of 3 inches shows the transition of a fresh-water fauna into marine forms. The occurrence of this particular band had been formerly noticed by Mr. Macnair and other observers, as described in papers read to and published by the Society, and it was noted that this persistent bed, which was very valuable for zonal purposes, had now been traced over a wide area, embracing Dalry (Ayrshire), Darnley, Milton of Campsie, the neighbourhood of Stirling, and again near Hamilton.

Mr. HARRY R. J. CONACHER exhibited bitumen from an intrusive sill at Dalmeny, occurring below the Burdiehouse Limestone. The sill at its intrusion had, by natural distillation of an adjacent oil shale, produced the hydrocarbon, which had collected in cavities of the igneous rock when it consolidated. The specimen exhibited might be called Elaterite. Its melting point was about 110 degs. Fahr.

Mr. J. W. REOCH, *Hon. Secretary*, exhibited specimens of native petroleum, viscid bitumen, and solid bitumen, derived from a dolerite sill ten feet or so below the Dunnet seam of oil shale at Broxburn, and evidently produced by a process of natural distillation from an oil shale 1 foot or so thick, lying between the Dunnet seam and the sill. The products of distillation could not get away, and under great pressure made room for themselves in the molten sill, which could not have been very hot, otherwise the hydrocarbon would have been converted into permanent gas. On cutting into the sill, cavities were found containing hydrocarbons of varying consistencies, as the specimens exhibited. The cavities are sometimes lined with carbonate

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of lime, sometimes carbonate of lime and magnesia, sometimes silica—all often in good crystals. Mr. Reoch also exhibited a specimen of Ozokerite from Loaninghill, a native paraffin wax, occurring in veins and cavities in the oil shales and adjacent sandstone strata; and he noted the interesting fact that Broxburn and its neighbourhood were lighted with candles made from this substance more than one hundred years ago—probably the first paraffin candles manufactured anywhere.

Remarks on these exhibits were made by various members, and the thanks of the meeting were awarded to the several contributors.

(Signed) ARCH. A. YOUNG.

SOCIETY'S ROOMS, 207 BATH STREET, 20TH NOVEMBER, 1911.

A joint meeting of the Geological Society of Glasgow with the Geographical Section of the Royal Philosophical Society of Glasgow was held here this evening—Dr. J. D. FALCONER, F.R.S.E., President of the Geographical Section, in the chair.

Professor J. W. GREGORY, D.Sc., F.R.S., &c., delivered a lecture on "Tripoli and Cyrenaica," treated from their geological and geographical aspects.

The lecturer, having dealt with his subject historically, said the traditions of the former value of Cyrenaica were still remembered, and inspired the hopes that the country might be restored to its former fertility. Turkey re-annexed it in 1835, but its development was beyond the Turk. Various explorers visited it, and were charmed by its scenery and fertility after rain. More than a dozen schemes have been advanced for the recolonisation of this land, and the glamour of the ancient glories of Cyrenaica has tempted Italy to annex the whole province of Tripoli. The invasion is not the result of a sudden impulse; for thirty years the Italian nationalists have advocated the annexation of Tripoli, and apparently Italy has been promised by the Powers that they would not prevent her. After the Berlin Treaty Italy turned her attention to Tripoli, and endeavoured to gain a firm foothold there by a policy of commercial penetration. She established missions, agencies, and schools, and Italian expeditions explored the country. But these efforts led to no definite result, except in so far as they hastened the French protectorate over Tunis, which was established in 1882. The commercial agencies were a financial failure; the Italian explorers reported that even the best parts of Cyrenaica had large tracts of barren soil and little water, and in 1896 Italian activity was suspended. Lately it has been renewed, and the change may be mainly due to irritation with the recent Turkish policy. The old Sultan, Abdul Hamid, took a keen personal interest in Cyrenaica, and though he objected to the Italian attentions to the country, he knew exactly when to stop obstructing them. The Young Turks have been less judicious; by reducing the Turkish garrison they left Tripoli more open to attack, and goaded Italy into action. The powers of aggravation possessed by the average Turkish official are unlimited, and the Italian merchants and agents

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on the coast no doubt had much to put up with, and Italy, in resentment, has seized the recent crisis in Morocco as her opportunity to secure Tripoli. The trade of the whole province of Tripoli is small; the annual exports and imports combined are only £800,000, and the total population is about a million, though the area is over 400,000 square miles. Italian writers regard the present poverty of Tripoli as due to Turkish misrule, and believe that their own Government would secure Tripoli a much larger population and trade. Tunisia, with about one-tenth the area of Tripoli, has a ten times larger trade. Tunisia has a population of 40 to the square mile, and Tripoli has only $2\frac{1}{2}$ to the square mile. The comparisons of Tunisia and Tripoli overlook the fundamental geographical differences between the two countries. Algeria, Tunisia, and Morocco are dominated by the Atlas Mountains, and those countries are so different from the rest of Africa that, according to various geographical classifications, they belong to Europe and not Africa. They have a rainfall varying from 20 to 40 inches. Tripoli, on the other hand, is a part of the Sahara. Owing to its more eastern position, it receives little rain from the Atlantic, and it must be compared not with Tunisia and Algeria but with the deserts to the south of them. Tripoli is an oasis like Biskra, in Southern Algeria. The former importance of the city of Tripoli was as the port of the Sahara and the Soudan. The Saharan hills can be seen from the town, and the great caravan route across the Sahara to the Niger and the Soudan started from Tripoli. But that trade is now dead owing to the diversion of the trade to the Niger and the Nile, and Tripoli has been cut off from the south by the junction of the French and the Egyptian territories to the south of it. The future of Tripoli depends upon its agricultural products, and to estimate its value for this purpose an expedition, of which the lecturer was the leader, was sent in 1908 to Cyrenaica, the most promising district of Tripoli, to investigate its suitability as a colony for Jewish refugees from Eastern Europe. The expedition visited Tripoli and then traversed Cyrenaica from Denna to Benghazi, and after inspection of the most promising districts, were forced to the conclusion that so small a proportion of the country is cultivable and the rainfall so scanty and uncertain that the country is quite unsuitable for agricultural colonies. The chief characteristics of the country and conditions which control its water supply and agriculture were explained by views and diagrams. Owing to the scarcity of water it has been suggested that the climate must have undergone a great change since classical times, but the expedition saw no reason to accept this conclusion, but convincing evidence that the climate during the Roman occupation was very similar to that of the present day. The classical population has been greatly exaggerated, and the commercial value of the country has been overrated, while the difficulties of its annexation have been underestimated. Cyrenaica is the sacred land of the Senussi, as that interesting order was established there; while it is of great practical importance, as through it they obtain all their arms and ammunition, which are smuggled from Crete in Greek fishing boats. An account was given of the history and principles of the Senussi and of reasons rendering it probable that they will offer the most deter-

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mined resistance to any foreign occupation of the country. The Italian difficulties, however, in Tripoli are small in comparison with the political handicap she is ready to accept; for in the case of any future trouble between France and Italy, the overwhelming French forces in Algeria and Tunisia would capture Tripoli, and Italy must be prepared either to double her fleet or let her colony go in case of a war with France.

On the motion of Mr. JOHN RENWICK and Dr. OSWALD, a hearty vote of thanks was awarded to the lecturer.

(Signed) ARCH. A. YOUNG.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH DECEMBER, 1911.

The third meeting of the fifty-fourth Session of the Geological Society of Glasgow was held here this evening—Mr. ARCH. A. YOUNG, *Vice-President* in the chair.

The Minutes of last meeting were read and adopted.

In the absence of Mr. John Renwick, Mr. CHARLES R. COWIE moved, in accordance with notice given at last meeting, "That £15 of the Society's funds be granted for Library purposes." The motion was unanimously carried.

The following members were elected:—

As Ordinary Members—Mr. Tullis Lawson, 141 Stanmore Road, Mount Florida, proposed by Mr. P. Macnair and Mr. J. W. Reoch; Mr. J. G. Roberts, Trees Cottage, Barrhead, proposed by Mr. P. Macnair and Mr. J. W. Reoch; Mr. G. W. Humphreys, M.A., 40 Derby Street, Glasgow, proposed by Mr. P. Macnair and Mr. J. W. Reoch; Mr. W. Wylie Stewart, 312 West Princes Street, Glasgow, proposed by Mr. G. W. Tyrrell and Miss A. T. Neilson.

As Associate Members—Mr. Geddes Anderson, 10 Wendover Terrace, Mount Florida, Glasgow, proposed by Mr. G. W. Tyrrell and Miss A. T. Neilson; Mr. Harry R. J. Conacher, 51 Grant Street, Glasgow, proposed by Mr. P. Macnair and Mr. J. W. Reoch; Mr. George Ross, c/o Edgar, 28 Smith Street, Hillhead proposed by Mr. G. W. Tyrrell and Miss A. T. Neilson; Mr. John Revie, Lochview Cottage, Townhead Road, Coatbridge, proposed by Mr. G. W. Tyrrell and Miss A. T. Neilson.

Mr. JAMES STEEL made feeling reference to the loss the Society had recently suffered by the death of one of their oldest members, Mr. John Wight, C.A., who had been an enthusiastic attendant at their meetings and excursions for many years and had taken a deep interest in the affairs of the Society, acting as their Treasurer from 1868 to 1901.

Mr. JAMES NEILSON read a paper entitled, "Notes on the Survey Memoir—The Geology of the Glasgow District." [See *Transactions*, vol. xiv., p. 323.]

A discussion followed, in which Mr. E. M. ANDERSON, of His Majesty's Geological Survey, replied to the several points on which Mr. Neilson had expressed disagreement. When the Hurlet datum line had been fixed by the Survey, it had been taken only as a con-

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venient base line, and the volcanic datum suggested by Mr. Neilson, although it might be suitable for the Glasgow area, could not be applied to other districts where these volcanic rocks were represented by quite different strata—strata in which he would be very glad if Mr. Neilson could find a palæontological break. As regarded Thorntonhall, a good many points had to be taken into consideration. He regretted Mr. Carruthers was not present himself to reply to Mr. Neilson, but mentioned the fact that in that district Mr. Carruthers had clearly confirmed the existence of strata above the Top Limestone of Thorntonhall leading up to the Hosie Limestone as exposed in the neighbourhood, and which could be exactly correlated with the strata occurring between the Hurlet and the Hosie Limestones in other districts. The cement band at Glenboig is recognised by the Survey as a variation of a band of ironstone which can be traced for a considerable distance in Lanarkshire. Mr. Anderson expressed much interest in Mr. Neilson's criticisms, and had no doubt that the difficulties could be cleared up.

Mr. PETER MACNAIR supported Mr. Neilson in his contention that the Hurlet datum line is of no scientific value. As regarded the Thorntonhall section, he briefly described sections on the north side of the Clyde which he had particularly examined, at Corrieburn, Craigenglen, Duntocher, and Hardgate, and compared these with the beds at Thorntonhall, where he maintained that we have exactly the same section from the Blackbyre seam up to the Hurlet Limestone. He was therefore here in clear agreement with the Survey.

Mr. G. W. TYRRELL, in referring to the divergent opinions that had been expressed, referred briefly to the work done by Mr. David Ferguson in the Lower Limestone Series, in which Mr. Tyrrell stated it had been conclusively proved that many fathoms below the Hollybush Limestone there is an enormous post of limestone called by Mr. Ferguson the Gleniffer Limestone. It occurs a few feet above the volcanic rocks, and is correlated by Mr. Ferguson with the Main Limestones of Ayrshire and Lanarkshire. This view, he considered, was worthy of notice.

Mr. JAMES NEILSON also read a paper on "A Visit to the Fairy Loch." This remarkable little loch is situated about four miles to the north of Luss, and lies in a little flat on the hillside, about 600 feet above Loch Lomond. It is only about 80 yards long by 20 to 30 yards wide, shallow round the edges, then steeply dipping down to a depth of 10 feet to 12 feet. Round the edges it is choked with weeds, but in the centre the water is very clear, and the peculiarity (from which it no doubt gets its name) is that on the bottom there occur several patches, from 2 feet to 5 yards in breadth, of a beautiful brilliant turquoise colour. Decaying sticks and twigs of vegetation which have become water-logged are also seen lying at the bottom coated with a deposit of this brilliant colour. No fish were observed in the water, although insect life abounds, and he could detect no evidence of springs being present, although a friend who visited it shortly afterwards considered he had done so. The loch is fed by a burn about 8 feet broad at its entrance, but which disappears when traced upwards from the loch for a quarter of a mile. At this point

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another stream, which had originally been a continuation of this stream, comes down, and is cut off very sharply, and runs northward. It would appear that the débris brought down was deposited at this sort of level part and banked up in front, so that the stream found an easier exit to the north. The hollow in which the loch lies appears to have been caused by a landslip. Mr. Neilson on his visit had not a chance of obtaining any of the coloured twigs to examine the nature of their coloured coating, but he brought the subject before the Society in the hope that it might be examined scientifically by some of the members.

At the close Mr. Neilson was accorded a hearty vote of thanks.

(Signed) JOHN RENWICK.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH JANUARY, 1912.

The fourth meeting of the fifty-fourth Session of the Geological Society of Glasgow was held here this evening—Mr. JOHN RENWICK, *Vice-President,* in the chair.

The Minutes of last meeting were read and adopted.

The following members were elected:—

As Associate Members—Mr. Geo. C. Bowie, c/o Jackson, Buckingham Drive, Carmyle, proposed by Mr. P. Macnair and Mr. J. W. Reoch; Mr. William Feely, 127 Glebe Street, Glasgow, proposed by Mr. P. Macnair and Mr. J. W. Reoch; Mr. W. J. Purves, c/o Arken, 8 Burnbank Terrace, proposed by Mr. P. Macnair and Mr. J. W. Reoch.

The CHAIRMAN made reference to a presentation of Books which had recently been made to the Society by Mr. James Neilson, including several rare editions and many volumes of great geological interest. Mr. Neilson was cordially thanked by the meeting for this handsome donation, which would form a valuable addition to the Society's library.

Mr. G. W. TYRRELL, A.R.C.Sc., F.G.S., read a paper on "The Igneous Geology of the Kilpatrick Hills." [See *Transactions,* vol. xiv., p. 219.]

In the discussion which followed, Mr. E. B. BAILEY, of H.M. Geological Survey, expressed his high appreciation of Mr. Tyrrell's work in this area, as well as in other districts which no petrologist had before opened up, and where information was greatly needed. His work was followed by petrologists in Britain with the greatest interest. After briefly touching on the manner in which Mr. Tyrrell had dealt with the chemical analyses, he stated that an extremely interesting point in his paper was the succession of the lavas, and how this is to be traced out. The question was how far the apparent succession was to be trusted. Comparing the succession at Ballagan with that further east at Kilsyth, we had in the west, coming on above the Old Red Sandstone, the Ballagan Beds, and above these a thick group of Jedburgh basalts capped by Markle basalts and mugearites; whereas at Kilsyth we found no Ballagan Beds, but on

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the top of the Old Red Sandstone an alternating group of Jedburgh and Markle basalts, with the Markle and mugearite group above the same as further west. He fancied that the Jedburgh group at Kilsyth represented the final thinning out of the whole western Jedburgh basalts, and that while the Ballagan sediments were forming there was at Kilsyth a volcano or series of volcanoes building up a complex cone of Jedburgh and Markle basalts. What we wanted to be clear about was whether such an apparent succession (as from Jedburgh to Markle type) in any district which we might be examining meant a succession in the evolution of rock types, or that it did not merely mean a group of interdigitating lavas supplied from vents which were to all intents and purposes contemporaneous. This indicated the need for further researches of the type that Mr. Tyrrell had brought forward. And there were many districts that might be tackled in the same way. In regard to the Cement-stones, he asked why these were so poorly developed on the north of the Kilpatrick Hills, while further east they are so well developed. Was it a matter of faulting, or had they merely thinned out to the west?

Dr. J. D. Falconer also expressed great interest in Mr. Tyrrell's paper. In regard to the classification, he asked if this was to be confined to Scotland, or was it to be extended to basalts in general. He noted the great similarity between the lavas of the Kilpatrick Hills and those of the Linlithgow Hills. In the basalts of the latter he had found nodules of olivine, and at Ardrossan basalts enclosing bodies of quartz, the occurrence of which was interesting, and it would be good to know if Mr. Tyrrell had found any such bodies in the lavas of the Kilpatrick Hills.

Mr. Peter Macnair also congratulated Mr. Tyrrell on his excellent paper. In regard to the section exhibited of Dunglass basalt, he noted the absence in it of the fine skeletal crystals of magnetite which are a remarkable feature of the rock. He also took notice of an area on the N.W. side of Dumbarton Rock of fragmental material full of pieces of the Ballagan Cement-stones, showing that these must at one time have stretched over Dumbarton Rock. In regard to the Whangie rock, he had difficulty in accepting this as an intrusion, and would like to know if there was any petrological evidence for its being so regarded. As to Burn Crooks, he had not been able to satisfy himself about the presence of the three necks there. Further, he had found no Ballagan Beds at Auchineden, but, so far as his examination went, the volcanics there immediately succeeded cornstones of the Old Red Sandstone, and he thought Mr. Bailey's explanation of the Kilsyth area was the interpretation here also.

Mr. George C. Watson also made remarks.

Mr. James Stark alluded to the well-known fact that in the Kilpatrick Hills zeolites occur in the lavas, whilst in the Old Red lavas in the east we have agates. He would be glad if Mr. Tyrrell would give an explanation of these facts.

Mr. Tyrrell, in thanking the various speakers, said he had much appreciated the discussion of his paper. He was fully at one with Mr. Bailey as to the interdigitation of the volcanics, and the apparent successions were thus fully explained. In regard to the Cement-

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stones on the north side of the Kilpatrick Hills, it was pretty clear that if these occurred in the Auchineden district they had been let down by a marginal fault. As to the classification of the lavas, he thought this must be confined to its own province, and that it would be confusing to extend it beyond the midland valley of Scotland, though correlations may be made between these and other basalts. He had not found any olivine nodules or quartz bodies in the lavas, the probable reason being that the Hillhouse type of basalts, and the monchiquites in which these would be most likely to occur, are not met with in the Kilpatrick Hills. In regard to the Whangie, he was pretty well convinced that the rock there was intrusive; he did not consider the rift there to be caused by slipping; the evidence seemed rather to favour the idea that earthquakes may have had something to do with it. The boundaries of the necks at Burn Crooks, though not seen, were to be inferred. The zeolites of the Kilpatrick Hills seem to be the last pneumatolytic products of the magma which has given rise to these more or less alkaline lavas, whereas the Old Red Sandstone lavas of the east belong to the calcic series, and therefore their products would be of a different nature, that is, watery products containing a good deal of silica in solution.

On the motion of the Chairman, a hearty vote of thanks was accorded to Mr. Tyrrell. (Signed) JOHN HORNE.

SOCIETY'S ROOMS, 207 BATH STREET, 15TH FEBRUARY, 1912.

The fifth meeting of the fifty-fourth Session of the Geological Society of Glasgow was held here this evening—Dr. JOHN HORNE, F.R.S., F.G.S., *President*, in the chair.

The Minutes of last meeting were read and adopted.

The following members were elected:—

As Ordinary Members—Mr. Matthew S. Brodie, 39 Wellmeadow Street, Paisley, proposed by Mr. Duncan Smith and Mr. J. W. Reoch; Mr. James W. Wordie, St. John's College, Cambridge, proposed by Mr. P. Macnair and Mr. J. W. Reoch; Mr. William Boyd, 213 St. Vincent Street, Glasgow, proposed by Mr. Wm. M'Creath and Mr. P. Macnair.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., *Joint Hon. Secretary*, and Mr. HARRY R. J. CONACHER exhibited specimens of *Posidonomya corrugata* from the shale above the Hosie Limestone at Corrieburn, and read detailed notes as to the occurrence of this fossil and its stratigraphical value. [See *Transactions*, vol. xiv., p. 309.]

Mr. JAMES NEILSON expressed his strong dissent from the conclusion that the top Limestone at Thorntonhall should be correlated with the Hurlet Limestone, and maintained that his own correlation of the beds at Thorntonhall and at Campsie, as shown in his paper recently read to the Society, was the correct one.

Mr. R. G. CARRUTHERS congratulated the exhibitors on the discovery of this fossil at Corrieburn. It strengthened the position of the Survey in their correlation of Campsie with Thorntonhall. In strati-

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graphy, however, the use of fossils must not be pushed too far; and lithology also had to be taken into account.

Dr. HORNE also emphasised the last point. He thought it was pretty clearly proved that the Calderwood Cement-stone undoubtedly overlies the position of the Thorntonhall Limestones.

Mr. W. R. SMELLIE, M.A., B.Sc., Baxter Demonstrator in Geology in the University of Glasgow, read a paper on "The Sandstones of the Upper Red Barren Measures to the East of Glasgow." [See *Transactions*, vol. xiv., p. 258.]

Professor J. W. GREGORY, in congratulating the lecturer on his paper and the interesting line of his research, stated that in the past the petrography of sedimentary rocks had been somewhat neglected. This class of work was of value as a contribution to physical geography and as shedding light on past physical conditions, and he trusted Mr. Smellie would continue his work on other deposits in the Glasgow district.

Mr. G. W. TYRRELL also expressed his congratulations. These sandstones were very interesting in a mineralogical sense, and he had rarely seen more beautiful heavy residues than those derived from them; the minerals were both perfect and rare. Had time permitted, there were many other interesting points he might have taken notice of.

Mr. JAMES NEILSON read a further note on the "Fairy Loch." From information he had received since his recent paper was read to the Society, he was now able to correct his former description in some of its details, and also to give a legendary account of how the loch came to be so named.

The hearty thanks of the meeting were accorded to the various contributors. (Signed) JOHN HORNE.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH MARCH, 1912.

The sixth meeting of the fifty-fourth Session of the Geological Society of Glasgow was held here this evening—Dr. JOHN HORNE, F.R.S., F.G.S., *President*, in the chair.

The Minutes of last meeting were read and adopted.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., *Joint Hon. Secretary*, and Mr. HARRY R. J. CONACHER exhibited specimens of *Spirophyton cauda-galli* Vanuxem sp. associated with fragments of crinoids and shells in a calcareous sandstone occurring between the lower and the upper post of the Hosie Limestone at Forking Burn, Campsie, and made descriptive remarks.

Mr. M. MACGREGOR, B.Sc., of H.M. Geological Survey, read a paper on "The Geology of the Garrion Burn at Overtown, Wishaw." [See *Transactions*, vol. xiv., p. 279.]

The paper was illustrated by a large-scale map and detailed sections of the ground.

A discussion followed, in which high appreciation was expressed of Mr. Macgregor's work.

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Mr. G. W. TYRRELL expressed his personal gratification at this evidence of his work since passing from Glasgow University to the Survey.

Mr. E. M. ANDERSON and Mr. PETER MACNAIR also made remarks on the paper.

Mr. R. G. CARRUTHERS pointed specially to its great value stratigraphically. To find anything like a continuous section exposed was an extremely rare thing, but here we now had, carefully mapped and described by Mr. Macgregor, a good standard section, which we could visit again and again for reference. The information yielded by such a natural section was of much higher value than evidence derived from bores. It would be of interest to make collections from the *Carbonicola* bands all through, and see if these could be used as good stratigraphical horizons.

Dr. HORNE also emphasised the importance of this section. It had been carefully mapped by Mr. Macgregor in extreme detail, and would serve as a typical sequence for the Carboniferous Series in this area, such as the Bilston Burn section had become in the Midlothian area. The "mussel" bands were well worthy of closer examination, and might yet turn out to be of great zonal value.

Mr. R. G. CARRUTHERS, F.G.S., of His Majesty's Geological Survey, read a paper entitled, "General Observations on the Oil-Shale Group." The distribution and peculiarities of the oil-shale group were briefly noticed, references being made to the deposition under shallow water and mudflat conditions present throughout, incursions of the open sea being extremely rare. Sun-cracked strata, "dessication breccias," and highly contorted beds occur at all levels, while abrupt lateral variations are frequent, the seams of oil-shale being affected in common with other strata. Certain horizons, however, are remarkably persistent, and of great value in boring for shale. Amongst these, two marine fossil bands (the Mungle and the Pumpherston shell-beds) have been traced over the whole region. There are well-marked axes of folding, running approximately north and south, which cross all the fields, and are of much use in predicting the probable structure of unproved ground. A short account was also given of the dolerite sills. These were separated into two classes (the teschenites and quartz-dolerites), which are distinct in petrological character, in age, and in behaviour; and the contact alterations produced by these intrusions present many features of interest, to which attention was called.

Remarks were made by Mr. J. W. REOCH, Mr. G. W. TYRRELL, Mr. E. B. BAILEY, and Mr. JAMES STARK. In reply to Mr. Stark, Mr. Carruthers stated that the question of the origin of ammonia and oil in the shales was a very difficult one to decide; and the only remark he would make in reply to Mr. Tyrrell was that the teschenites were a good deal earlier in age than the quartz-dolerites.

Dr. HORNE, in alluding to the fact that Mr. Carruthers had been enabled to draw important conclusions from the evidence of old bore cores submitted to him, dwelt on the intense value of the preservation of these cores, and on the importance of the Geological Survey having access to every bore that is put down, in order that the cores might

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be thoroughly examined; otherwise the evidence to be derived from them might be misinterpreted, and in many cases mining engineers had been found to be entirely wrong in their conclusions.

The hearty thanks of the meeting were accorded to the contributors.

(Signed) ARCH. A. YOUNG.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH APRIL, 1912.

The seventh meeting of the fifty-fourth Session of the Geological Society of Glasgow was held here this evening—Mr. ARCH. A. YOUNG, *Vice-President*, in the chair.

The Minutes of last meeting were read and adopted.

Mr. W. H. Herdsman, 144 Wellington Street, Glasgow, as proposed by Mr. Peter Macnair and Mr. J. W. Reoch, was elected an Ordinary Member.

Mr. HARRY R. J. CONACHER exhibited specimens of the Pendleside fauna from Calderwood Glen. These were now known to occur on three horizons in the glen, one of which had been known for some time, the other two being fresh discoveries. The specimens shown were from the lowest of these horizons, just above the Lady Ann Coal in the Calciferous Sandstone Series. The chief characteristic fossil as exhibited was *Posidonomya becheri*, another characteristic fossil being *Pterinopecten papyraceus*. Calderwood Glen is the only known locality in Scotland for *P. becheri*. Mr. Conacher also exhibited specimens of *Posidonomya corrugata* from the Calderwood Cement Limestone, as well as from Shields Burn, Campsie, the former being a new locality for this fossil.

Mr. JAMES STEEL read a biographical notice of the late Mr. John Wight, C.A., a former Treasurer of the Society. Mr. Wight's ancestors were connected with Ormiston Lodge, in the county of Midlothian, where his youth was spent. He received an early training as a lawyer in Edinburgh, but, on getting an appointment in the town-clerk's office in Glasgow, he migrated west. Ultimately, however, he followed out here the business of an accountant, as which he was held in high repute and esteem. A man of a retiring nature, but with a keen taste for reading and intellectual pursuits, he took a deep and lively interest in the affairs of this Society throughout his long connection with it; and though taking no outstanding part in the way of geological contributions, he was an enthusiastic attendant for many years at the meetings and excursions of the Society. Joining it in 1866, he became Honorary Treasurer in 1868, holding that office for thirty-three years, until 1901, and remaining a member up till his death, on 7th December, 1911, at the ripe age of eighty-five years.

Mr. G. W. TYRRELL, A.R.C.Sc., F.G.S., read a paper on "Variolitic Basalts from Upper Loch Fyne and from Skye." [See *Transactions*, vol. xiv., p. 291.]

The paper was fully illustrated by diagrams and microscopic slides, specimens as well being shown.

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Mr. ALFRED HARKER, M.A., F.G.S., of Cambridge, who was present, expressed his interest in this paper, and made remarks on the occurrence of these variolitic rocks in the West of Scotland and on their characters.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., read "Notes on the Occurrence of Gypsum in Shale at Shields Burn, Campsie." The gypsum has here been formed as a secondary structure in the bedding planes of the shale, where it occurs in beautifully developed miniature crystals having the characteristic forms of selenite. These are commonly arranged in regularly radiating stellate groups, the crystals being often so symmetrically grouped and closely packed together as to yield a black cross of extinguished light when viewed under crossed nicols. Many of the crystals also occur as arrow-head twins. The specimens can easily be picked off the shale quite ready for mounting as microscopic objects. The mode of occurrence of these crystals at Shields Burn is rather interesting—they are here accompanied by specimens of *Posidonomya corrugata* associated with iron pyrites. The author thought they threw some light on the question of the thin films of gypsum which occur in the eyed, or "eenie" coal of Cambuslang, described by Mr. Clough and by himself; we had here some radial structures closely corresponding to those found in the eenie coal. Examples of crystals of gypsum similarly occurring at Craigenglen, as found by Mr. J. W. Reoch, were also noted, and specimens from both localities were exhibited.

The hearty thanks of the meeting were awarded to the contributors.

(Signed) ARCH. A. YOUNG.

SOCIETY'S ROOMS, 207 BATH STREET, 9TH MAY, 1912.

The eighth meeting of the fifty-fourth Session of the Geological Society of Glasgow was held here this evening—Mr. ARCH. A. YOUNG, *Vice-President*, in the chair.

The Minutes of last meeting were read and adopted.

Mr. William Munro, 181 Trongate, Glasgow, as proposed by Mr. D. M. Cowan and Mr. Peter Macnair, was elected as an Ordinary Member.

Professor GREGORY, *Vice-President*, read a letter which he had received from Professor Lapworth, as follows:—

38 Calthorpe Road, Edgbaston,
Birmingham, 23rd March, 1912.

Dear Professor Gregory,

Many thanks for your exceedingly kind letter informing me that the Senate have invited me to accept the degree of LL.D. of the Glasgow University. . . .

Of course it will be a great pleasure for me to accept the honour, not only for its own sake, but because the University awarding it is the University of Glasgow, and the degree is another link binding to the dear old Geoogical Society of Glasgow. The members of that

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Society were among the very first to invite me (forty years ago) to speak on my earliest geological work; and the warm-hearted and generous reception they then gave me was, as you will easily understand, the very best stimulus possible to a nervous beginner, and I have never forgotten it or failed to be really grateful for it. The interest, good fellowship, and sympathy they gave me at that time they have shown in countless ways ever since. . . .

Believe me, sincerely yours,

(Signed) CHARLES LAPWORTH.

Professor J. W. GREGORY, D.Sc., F.R.S., *Vice-President*, read a paper on "The Polmont Kame, and the Relation of Kames to other Glacial Deposits." [See *Transactions*, vol. xiv., p. 199.]

The paper was discussed by Messrs. Alex. Stevens E. M. Anderson, of H. M. Geological Survey; Charles R. Cowie, George C. Watson, and Dr. J. D. Falconer.

Mr. COWIE remarked that he had observed no large boulders in the Polmont Kame—only small gravel which was water-washed as if carried along by the bed of a stream—and he was rather inclined to the theory that it had been formed by a sub-glacial river running from west to east as the glacier receded from east to west.

Mr. E. M. ANDERSON expressed his interest in the subject. He described the appearance of the Kame inside the estate of Callander. As to its origin, he agreed that it bore no resemblance to the Swedish osar. He would not care to differ from Professor Gregory, but a difficulty in accepting it as a marginal deposit was that after the melting of the glacier one would expect such a deposit to have one steep side and one gentle slope, whereas this had about equal slopes on both sides. He suggested the possibility of its formation by deposits carried into a deep crack or crevice running parallel to the margin of the ice. He could not conceive it to have been formed under the glacier; it must have been formed near the margin of the glacier, if not exactly at it.

Dr. J. D. FALCONER found the paper full of interest and suggestion. He thought the terms "marginal" and "radial," as applied to kames and eskers, very much better than "transverse" and "longitudinal." It would be interesting if Professor Gregory would say if the Irish eskers have a banded structure.

Professor GREGORY briefly replied to the several points raised. If eskers occurred in Scotland, you would expect to find them rather in the low country than in hilly districts. In reply to Mr. Cowie he stated that in a good many parts of the Polmont kame he had found a fair number of boulders; these were sub-angular, as if pushed down rather than rolled in a river. The changes of level introduced a difficulty in the theory that the kame has been formed by a river. As to the Malaspina glacier referred to by Mr. Watson, if the ice was stagnant at its margins you would still get certain evidence of the annual flooding. He agreed with Mr. E. M. Anderson that it was a marginal formation; but it was formed by the wash of water down the ice, and not by the material having been merely shot down as the débris of an ordinary moraine. He stated that

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there is a seasonal banding in some of the Irish eskers which he did not think had ever been described.

Mr. JAMES W. REOCH, *Joint Hon. Secretary*, read a paper entitled, "Notes on the Occurrence of Chalcedony, Agate, and Crystalline Quartz in the Lavas of the Campsie Hills." [See *Transactions*, vol. xiv., p. 303.]

Remarks on this paper were made by Professor Gregory, Mr. J. G. Roberts, and Mr. E. M. Anderson.

Mr. W. H. HERDSMAN read a paper entitled, "A New Theory of the Earth's Structure, Geologically Considered." The theory postulates the earth to be a hollow metallic sphere in vibrant equilibrium on a spherical centre situated within the metallic mass. The author claims that a hollow globe is the natural condition which the earth must have assumed by the laws of gravity when solidifying from a fluid state in rotary motion and with the moon in proximity as now; that the principal mass of the earth is of nickel-iron, with a rocky crust less than 50 miles thick; volcanic phenomena are confined to this rocky crust; that the metallic sphere is solid and probably at a very low temperature, consequently all heat in the earth's crust is due to the atomic transformation of radium in the crustal rocks, or is locally generated by internal energy. Rock movements resulting in the folding, overthrusting, or crushing of the rocks, and all igneous and volcanic manifestations, are claimed by the author to be indications of this internal earth energy brought into action when the normal condition of balanced equilibrium has been disturbed, as it is constantly being disturbed, by surface erosion and other causes. The rock movements and thermal phenomena mentioned are, in the author's opinion, evidences of the manner in which the earth's normal equilibrium is being restored. The author finds justification for assuming a nickel-iron structure from the analogy of meteorites, which have always been regarded as derived from the earth's primary matter, or from that of some disrupted world. Confirmation is found of this view in blocks of nickel-iron found in Greenland, and proved to be of terrestrial origin. Support is also found in the mean density of the earth, which is already known to be about 5·5. If one-thirtieth of the earth's volume is regarded as rock of a density of 3, equal to a crust of 45 miles thick, and two-thirds be taken as of nickel-iron of a specific gravity of 8·1, the remaining three-tenths representing the central void = 0, then the average specific gravity works out at 5·50. The author draws attention to numerous other circumstances tending to give support and confirmation to his theory, including the rigidity as satisfying the demands upon which Lord Kelvin always insisted. The vulcanists, seismologists, and radioactivists are all in agreement that the rock matter known to us at the surface terminates at a depth of less than 50 miles, and is succeeded by matter of a totally different character which is homogeneous and of a uniform temperature throughout. Further proof is found by the author in the fact indicated by the seismometers that the ground on which we dwell is incessantly in a state of tremulous motion, which only a balanced metallic spring such as is the earth could give. The

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economic results which may follow the confirmation of the author's theory were, in conclusion, briefly referred to. The paper was illustrated by an explanatory diagram.

Discussion of the paper was held over till a future meeting owing to lack of time.

The thanks of the Society were awarded to the several contributors.

(Signed) JOHN HORNE.

EXCURSIONS FOR SEASON 1912.

To Baldow and Craigen Glens, Campsie, on Saturday, 20th April—Mr. Harry R. J. Conacher, conductor. To examine two exposures of limestone in the Calciferous Sandstone Series; the "White" Limestone and Alum Shale, and the position of the Coal and Main Limestone of the Hurlet, and then the strata up to and just above the Blackhall. This is a continuous section, and in Craigen Glen we find another section of the seams below the Hurlet, whose sequence is not so clear, but the exposure is much larger. In Craigen Glen fossils may be obtained from these classic beds.

To Thorntonhall Quarries, on Saturday, 4th May—Mr. G. C. Watson, conductor. To demonstrate the correlation of the strata exposed in this famous section with sections at Hurlet, Duntocher, and Corrie. The section shows volcanic conglomerates, overlaid by a fossiliferous shale, passing into a 12-feet post of marine limestone. This limestone is succeeded by beds of fresh or brackish water deposits, with two fish beds, entomostracan shales, a thin cornstone, also a 3-feet green nodular limestone. The datum line fixed by the Survey separating the Calciferous Sandstone Series from the Lower Limestone Series here crosses the section. The beds above this division consist of the Hurlet seams, the Hurlet Coal being here absent.

To Corrieburn, Stirlingshire, on Saturday, 18th May—Mr. Peter Macnair, F.R.S.E., F.G.S., conductor. The streams at Corrieburn exhibit a practically continuous section of the Lower Limestone Series. The beds, which immediately underlie the Hurlet Limestone, consist of black shales with sandstone bands, which pass downwards into volcanic muds and conglomerates resting upon the lavas. In the most westerly stream these are succeeded by the White Coralline Limestone, the Hurlet Coal, and the Hurlet Limestone. Proceeding eastwards the next stream shows the Blackhall, overlaid by black shales and septarian nodules, while the most easterly stream shows the Hosie Sandstones and Bellerophon Limestone, capped by black shales containing *Posidonomya corrugata*. The rocks are highly fossiliferous, and the stream sections exhibit many interesting physical features. The sill of intrusive dolerite seen in contact with the Index Limestone at Gavell was also examined.

To Elie and St. Monans, Fife, on Thursday, 23rd May (Victoria Day)—Dr. John Horne, F.R.S., F.G.S., conductor. The object of this excursion was to examine (1) A volcanic neck in lower Carboniferous rocks; (2) the Lower Limestone group of the Carboniferous

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Limestone Series; (3) upper portion of the Calciferous Sandstone Series.

To Bothwell Park Brickworks and Quarries, on Wednesday, 5th June (evening excursion)—Mr. Wm. R. Smellie, M.A., B.Sc., conductor. To examine exposures of Sandstones of the Upper Red Barren Measures, sections of boulder clay and alluvial clay.

To Rumbling Bridge, on Saturday, 8th June (joint excursion with Edinburgh Geological Society)—Dr. B. N. Peach, F.R.S., F.G.S., conductor. To follow the course of the river Devon from Rumbling Bridge to Vicars Bridge. A post-glacial gorge cut in Lower Old Red agglomerate was examined, and the Ochil Fault crossed. Next the Ballagan Beds, with intrusive sill of dolerite giving rise to Cauldron Linn Waterfall, was seen, and a cornstone on top of Upper Old Red Sandstone Series.

To Hurlet, Blackbyre, Hollybush, Blackhall, on Wednesday, 12th June (evening excursion)—Mr. Peter Macnair, F.R.S.E., F.G.S., conductor. To examine the limestones of the Lower Limestone and Calciferous Sandstone Series as they are developed at the above typical localities. The Blackhall Limestone was first examined at Hurlet, and the position of the Hurlet outcrop also traced. The Blackbyre Limestone was examined at Blackbyre Farm, the Hosie Limestone at Barrhead, the Hollybush at Hollybush Farm. The sections at Nethercraigs were also visited.

To Campbeltown, for West Coast of Kintyre, on Saturday, 15th June—Mr. William Sinclair, conductor. To study the boulder clay, marine and sub-aerial denudation: the 25-feet raised beach, showing rock stacks (schistose), the weathering being very well shown; and also an old sea floor at about 50 feet above present sea-level. The special part of the coast is from the fifth to the tenth milestone on the Tarbet Road.

To the "Fairy Loch," Loch Lomond, on Saturday, 22nd June—Mr. James W. Reoch, conductor. The "Fairy Loch" is situated on the west bank of Loch Lomond, about midway between Tarbet and Luss, and lies in a little flat on the hillside about 600 feet above sea-level. The Survey map here shows a small patch of schistose grits faulted against the prevailing mica-schists of the district. This little loch is remarkable for the clearness of its water, and from the fact that at the bottom there occur several patches of a brilliant turquoise colour. The object of the excursion was to examine the Lochan and its surroundings, and to investigate and discuss the cause of these coloured patches, as suggested by Mr. James Neilson in a paper recently read to the Society. It is called in Gaelic, "Lochan Uaine"—the little green loch—but a legendary explanation of the green patches has earned for it the name of "Fairy Loch."

To Mauchline, on Saturday, 7th September—Mr. B. K. N. Wylie, M.A., B.Sc., conductor. The party first visited the great Quarries in the "Permain" Red Sandstones. Then the gorge in the River Ayr was examined from the "Permian" Red Sandstones at Haugh to the lavas and the tuffs at Howford Bridge; at the latter locality an intrusion of the rare rock analcite-syenite was seen.

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To Garrion Burn, Wishaw, on Saturday, 21st September—Mr. M. Macgregor, M.A., B.Sc. (H.M. Geological Survey), conductor. The section visited includes the strata lying between the Kiltongue Coal and the Upper Coal, and also the probable position of the Palacecraig Ironstone. Excellent exposures are seen of the following horizons:—Kiltongue Musselband, Ladygrange Coal (and Bellside Ironstone), Virtuewell Coal, Blackband and Musselband Coal positions, Humph Coal, Main Pyotshaw positions, and Upper Coals. Several "Musselband" horizons occur, and opportunities for collecting are good.

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ABSTRACT OF THE TREASURER'S ACCOUNTS FOR THE YEAR ENDED 30TH SEPTEMBER, 1911.

CASH ACCOUNT.

RECEIPTS.

To Cash in Bank on Deposit,	£60 0 0	
,, Do. in Treasurer's hands,	4 14 3	
,, Do. Mr. C. R. Cowie's Donation,	2 0 7	
		£66 14 10
,, Subscriptions for current year (including 5 new Ordinary Members)—136 at 10/,		68 0 0
,, Do. 3 at 7/6,		1 2 6
,, Do. Arrears—4 at 10/,		2 0 0
,, Life Membership Subscription,		2 0 0
,, Associate Members' Subscriptions—23 at 2/6,		2 17 6
,, Mitchell Library for copies of *Transactions* and for back numbers,		2 15 2
,, Handbooks and Catalogues sold, per Hon. Librarian,		1 1 10
,, Interest on Funds,		5 12 0
,, Do. Mr. C. R. Cowie's Donation,		3 5 11
		£155 9 9

EXPENDITURE.

By *Transactions*—		
Printing and Publishing Vol. XIV., Part 1, and for Reprints of Papers,	£37 12 3	
Postages and Outlays *re* do.,	3 1 1	
		£40 13 4
,, Library—New Books and Bookbinding Maps and Magazines,		12 17 1
,, Printing and Postage of Circulars and Excursion Booklets, and Advertising,		19 4 8
,, Rent, Insurance, and Attendance,		10 10 0
,, Disbursements by Hon. Secretaries, Postages, Stationery, and Petty Expenses,		3 6 10
,, Collector's Commission,		2 16 9
,, Lantern Expenses,		1 10 9
,, Subscription to Marine Biological Association, 1911,		1 1 0
,, to Palæontographical Society, 1911,		1 1 0
,, Mr. C. R. Cowie's Donation—		
Interest to Martinmas, 1910, paid to Glasgow University,	£1 16 10	
Do., to Glasgow and West of Scotland Technical College,	1 16 9	
		3 13 7
,, Cash in Bank on Deposit,	£54 0 0	
,, Cash in Treasurer's Hands,	3 1 10	
,, Do. Mr. C. R. Cowie's Donation,	1 12 11	
		58 14 9
		£155 9 9

LIFE SUBSCRIPTION ACCOUNT.

Sept. 30, 1911.—To Balance to Credit,		£177 5 0	
			£177 5 0
September 30, 1910.—By Balance from last Account,		£175 5 0	
September 30, 1911.— ,, Subscription during Year,		2 0 0	
			£177 5 0

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ABSTRACT OF THE TREASURER'S ACCOUNTS FOR THE YEAR ENDED 30TH SEPTEMBER, 1911.

Mr. CHARLES R. COWIE'S DONATION.

Sept. 30, 1911.—To Glasgow University, one-half of Interest to Martinmas, 1910,		£1	16	10	
,, Glasgow and West of Scotland Technical College, one-half of Interest to do.,		1	16	9	
Balance to Credit,		101	12	11	
	£105	6	6		
Sept. 30, 1910.—By Balance from last Account,				£102	0 7
Sept. 30, 1911.— ,, One year's interest to Whitsunday, 1911,				3	5 11
				£105	6 6

STOCK ACCOUNT.

To Life Subscription Account,		£177	5	0	
,, Mr. Charles R. Cowie's Donation and accrued Interest,		101	12	11	
,, Capital Account,*		549	16	10	
	£828	14	9		
By Invested with Campbeltown Corporation under Mortgage at 3½ per cent.,				£170	0 0
,, Cash in Bank and in Hand,				57	1 10
				£227	1 10
,, Property—Books in the Library,				£440	0 0
Furniture, Bookcases, & Microscope,				60	0 0
				500	0 0
,, Mr. Charles R. Cowie's Donation—Invested with Campbeltown Corporation under Mortgage at 3½ per cent.,				£100	0 0
,, Do., Interest accrued to Whitsunday, 1911,				1	12 11
				101	12 11
				£828	14 9

* NOTE.—Subject to cost of publishing *Transactions*.

GLASGOW, *3rd November*, 1911.—Examined, compared with relative Vouchers and Securities, and found correct, the balance in Treasurer's hands being Four Pounds Fourteen Shillings and Ninepence; Three Pounds One Shilling and Tenpence being due to Society, and One Pound Twelve Shillings and Elevenpence being Interest accrued on Mr. Charles R. Cowie's Donation.

D. PEARSON,
ARCH. MACINTYRE, } *Auditors.*

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For Three Years.

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For Two Years.	*For One Year.*
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